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RESEARCH MEMORANDUM

ALTITUDE WIND TUNNEL INVESTIGATION OF THE PERFORMANCE OF COMPRESSOR, COMBUSTOR, AND TURBINE COMPONENTS OF PROTOTYPE J47D (RX1-1) TURBOJET ENGINE

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

ALTITUDE WIND TUNNEL INVESTIGATION OF THE PERFORMANCE OF COMPRESSOR, COMBUSTOR, AND TURBINE COMPONENTS OF PROTOTYPE J47D (RX1-1) TURBOJET ENGINE

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SUMMARY

As a portion of an over-all performance investigation of the prototype J47D (RX1-1) turbojet engine, the performance of compressor, combustor, and turbine components was determined in the Lewis altitude wind tunnel over a range of altitudes from 5000 to 55,000 feet and at flight Mach numbers from 0.19 to 0.92. Investigations were conducted with the engine operating on an electronic control schedule and also with a two-lever control system by which fuel flow and exhaust-nozzle area could be controlled separately. Two combustion-chamber configurations were investigated.

Peak compressor efficiency occurred in the range of corrected engine speeds from 6000 to 6500 rpm for all flight conditions investigated. A maximum compressor efficiency of 86 percent was obtained at an altitude of 5000 feet, a flight Mach number of 0.19, and a corrected engine speed of 6000 rpm. Compressor efficiency decreased with increasing altitude because of the reduction in compressor Reynolds number. Reynolds number had no effect on corrected air flow at altitudes below 25,000 feet but at higher altitude air flow decreased with decreasing Reynolds number.

When the engine speed or the flight Mach number was increased, or when the altitude was reduced, an increase occurred in combustion efficiency, primarily because of the corresponding increase in combustion-chamber inlet pressure and temperature. Combustion efficiencies for all flight conditions investigated correlated when plotted as a function of the fuel-air ratio and the combustion-chamber parameter $\frac{P_3 T_3}{V_3}$ where P_3, T_3, and V_3 are the stagnation pressure, stagnation temperature, and velocity, respectively, at the combustor inlet.

For engine speeds over 4000 rpm, turbine-efficiency values were between 79 and 86 percent for altitudes from 5000 to 55,000 feet and a flight Mach number of 0.19. Variations of exhaust-nozzle area or of flight Mach number from 0.19 to 0.92 had no appreciable effect on turbine efficiency. 2307

INTRODUCTION

An extensive investigation was conducted in the NACA Lewis altitude wind tunnel to determine the over-all and component performance of the prototype J47D (RX1-1) turbojet engine. Previous investigations of an earlier model of the J47 turbojet engine are reported in references 1 to 5. The principal differences between these engines were: (1) The diameter of the first two stages of the compressor of the J47D turbojet engine was increased resulting in a rated-air-flow capacity about 3 percent greater than earlier models; (2) the prototype J47D (RX1-1) turbojet engine is equipped with an afterburner, a variable-area exhaust nozzle, and an integrated electronic control system. The investigation of the prototype J47D (RX1-1) was made to determine the effects of these changes, and to determine the altitude performance of the electronic control system. Engine performance and operational characteristics are reported in references 6 to 8.

The steady-state performance characteristics of compressor, combustor, and turbine components while the engine was operating on the electronic control schedule at simulated altitudes from 5000 to 55,000 feet with a flight Mach number of 0.19, and with flight Mach numbers from 0.19 to 0.92 at an altitude of 25,000 feet is presented herein. In addition to the data obtained on the control schedule, data are presented showing the effect of varying the exhaust-nozzle area at each of several fixed engine speeds at simulated altitudes of 15,000 and 45,000 feet with a flight Mach number of 0.19. During the investigation, the engine combustion chambers were modified to improve the altitude starting characteristics. A comparison of the performance characteristics of the original and modified combustors is included herein. Component-performance data are presented in tabular form as well as graphical form.

APPARATUS

The J47D turbojet engine (without afterburning) has a sea-level static-thrust rating of 5670 pounds with an engine speed of 7950 rpm and a turbine-outlet-gas temperature of 1275° F. A more detailed description of the engine is given in reference 7. The electronic control was scheduled for a compromise between optimum steady-state performance and the desired acceleration characteristics of the engine. In steady-state operation without afterburning, engine speed and exhaust-nozzle area were considered scheduled as a function of the position of the thrust selector.

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<u>Compressor</u>. - The 12-stage axial-flow-compressor rotor (fig. 1(a)) has an outside diameter of 30.1 inches at the leading edge of the first-stage blading and from the third stage aft the blade tip diameter is constant at 28.9 inches. The compressor has a single row of inlet guide vanes and a double row of outlet guide vanes. The compressor rated air flow is 99 pounds per second at a pressure ratio of 5:1.

<u>Combustors</u>. - Two combustor configurations were used in this investigation. In order to improve the altitude starting characteristics, the original combustors were modified by increasing the size of the cross-fire tubes (fig. 1(b)), by adding deep immersion, opposite polarity spark plugs and by adding baffles to some of the secondary air holes in the combustor liners to direct the air flow to the center of the combustion zone (fig. 1(c)).

Each of the eight combustors had a duplex fuel nozzle to maintain a desirable fuel-spray pattern for both high and low fuel flows. An automatic flow divider distributed the fuel between the high-flow and the low-flow sections of the nozzles.

<u>Turbine</u>. - The single-stage impulse turbine rotor had a tip diameter of 34.3 inches and a blade height of $3\frac{3}{4}$ inches. The turbine rotor is shown in figure 1(d).

INSTALLATION AND INSTRUMENTATION

<u>Installation</u>. - The engine was mounted on a wing in the wind-tunnel test section. Dry refrigerated air was supplied to the engine inlet through a duct from the tunnel make-up air system. In this system, air is throttled from approximately sea-level pressure to an engine-inlet stagnation pressure corresponding to the desired flight condition.

<u>Instrumentation</u>. - Location of the instrumentation used to determine component performance is shown in figure 2. The temperatures measured at the exhaust-nozzle inlet (station 8) were used as the turbine-outlet temperatures because it was found that the temperatures measured at station 6 were affected by radiation because of the proximity of the turbine.

The pressures at stations 1, 6, and 8 were measured with Alkazene manometers, whereas those at stations 3 and 4 were measured with mercury manometers. The temperatures at stations 1 and 3 were measured with iron-constantan thermocouples and those at stations 6 and 8 were measured with cromel-alumel thermocouples. The values of pressure and temperature used to determine component performance were arithmetic averages of the values measured at each station.

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PROCEDURE

For unscheduled engine operation, a two-level control system was employed by which engine speed and exhaust-nozzle area were controlled separately. With this system and with the original combustors installed, data were obtained over a range of exhaust-nozzle areas at several fixed engine speeds, at altitudes of 15,000 and 45,000 feet, and a flight Mach number of 0.19.

With the engine on the electronic control schedule and with the original combustors installed, data were obtained at simulated altitudes from 5000 to 55,000 feet with a flight Mach number of 0.19, and at 25,000 feet with simulated flight Mach numbers from 0.19 to 0.92. With the modified combustors installed, data were obtained at altitudes of 6000, 35,000, and 45,000 feet with a flight Mach number of 0.19.

The compressor-inlet stagnation pressure was set to correspond to the desired flight condition assuming 100-percent diffuser recovery. The inlet-stagnation temperatures were set at NACA standard values for each flight condition, except that temperatures below 437° R could not be obtained.

Fuel conforming to specification MIL-F-5624 (AN-F-58a) with a lower heating value of 18,900 Btu per pound was used throughout the investigation.

Symbols used in this report are defined in appendix A and the method used in calculating gas flow is included in appendix B. Methods used in calculating flight Mach number, temperature, and turbine efficiency are presented in reference 4. Methods of calculating compressor and combustion efficiency are given in references 2 and 5, respectively.

RESULTS AND DISCUSSION

Component-performance data are presented in numerical form in tables I to III.

Compressor

Unscheduled operation. - Compressor performance maps for altitudes of 15,000 and 45,000 feet and a flight Mach number of 0.19 are presented in figure 3. Superimposed on these maps are lines of constant exhaust-nozzle area, representing the maximum and minimum areas scheduled by the electronic control, and one intermediate area. When the exhaust-nozzle area was changed from 2.94 to 2.22 square feet, compressor efficiency changed by less than 2 percent at all engine speeds and for either flight condition. Interpolation shows that at an altitude of 15,000 feet, this change in nozzle area caused an approximately 10-percent increase in pressure ratio at a corrected engine speed of 8000 rpm, and a 6-percent increase at 6000 rpm. At an altitude of 45,000 feet, compressor pressure ratio was increased about 14 percent at 8000 rpm and 9 percent at 6000 rpm.

Scheduled operation. - The electronic control schedules the relation between exhaust-nozzle area and engine speed N as shown by the sea-level curve in figure 4(a). As altitude is increased at a constant flight speed, compressor-inlet temperature decreases and therefore at a given engine speed N corrected engine speed $N/\sqrt{\theta_1}$ increases with altitude; thus the exhaust nozzle-area varies with altitude for a given $N/\sqrt{\theta_1}$ (fig. 4(a)). A similar relation occurs when flight speed is varied at a given altitude.

The experimental variation in exhaust-nozzle area with corrected engine speed for various altitudes from 5000 to 55,000 feet at a flight Mach number of 0.19 is shown in figure 4(b). Because of refrigeration limitations, inlet temperatures of about -20° F were used for the investigations at altitudes over 25,000 feet instead of the standard inlet temperatures for these flight conditions. Therefore the relation between corrected engine speed and nozzle area was different from that which would have occurred had standard temperatures been used. When figures 4(a) and 4(b) are compared, it is apparent that at a corrected engine speed of 7000 rpm the nozzle area was about 2.7 square feet for altitudes of 35,000 feet and over, and that the area would have been about 2.85 square feet with standard inlet temperatures. Interpolation in figure 3(b) shows that this change in area would change compressor pressure ratio only about $1\frac{1}{2}$ percent. The corresponding effect on air flow and compressor efficiency is negligible.

Effect of altitude on compressor operating lines. - Operating lines obtained with the electronic control schedule for altitudes from 5000 to 55,000 feet and a flight Mach number of 0.19 are presented in figure 5(a). The position and the slope of the corrected engine speed lines on this plot were determined by interpolation from figures 5(b) and 3, respectively. The operating lines were coincident for altitudes from 5000 to 25,000 feet, and for altitudes over 25,000 feet engine air flow decreased at a given corrected engine speed. This reduction in air flow with altitude is attributed to the decrease in Reynolds number with altitude. It is also apparent in figure 5(a) that the constant speed lines cross corresponding compressor operating lines at the same value of compressor pressure ratio at all altitudes. Therefore, if pressure ratio were plotted against corrected engine speed, the data for all altitudes investigated would fall on a common curve. Investigation of an earlier model of the J47 turbojet engine (reference 2) showed a slight increase in compressor pressure ratio with altitude at given corrected engine speeds above 6000 rpm. This difference might be attributed partly to the increase in exhaust-nozzle area with altitude due to the control schedule. As previously discussed, if standard inlet temperatures had been used for the investigations at altitudes over 25,000 feet, the exhaust-nozzle area would have been slightly larger and the compressor pressure ratio would have been about $1\frac{1}{2}$ percent lower at corrected engine speeds of approximately 7000 rpm. However, this variation in pressure ratio was within the accuracy of the data. The compressor air flow at an altitude of 5000 feet and at a corrected engine speed of 7950 rpm was about 100 pounds per second.

Effect of flight Mach number on compressor operation lines. - Compressor operating lines on the electronic control schedule at an altitude of 25,000 feet and flight Mach numbers from 0.19 to 0.92 are plotted in figure 6(a). The corrected engine speed lines were interpolated from figure 6(b).

The constant corrected engine-speed lines are coincident for all flight Mach numbers investigated, indicating that the Reynolds number change was too small to affect air flow.

At a given corrected engine speed, compressor pressure ratio decreased with increasing flight Mach number. This relation occurs because of the increase in compressor-inlet pressure with flight Mach number so that a given corrected engine speed can be maintained with a smaller pressure rise across the compressor.

Compressor efficiency. - Curves showing the effect of corrected engine speed, altitude, and flight Mach number on compressor efficiency are presented in figure 7.

For all flight conditions investigated, the peak compressor efficiency occurred in the region of corrected engine speeds between 6000 and 6500 rpm somewhat below the cruising speed range. Efficiency decreased sharply when the engine speed was reduced or increased from this range of speeds. A maximum compressor efficiency of 86 percent was obtained at an altitude of 5000 feet, a flight Mach number of 0.19, and a corrected engine speed of 6000 rpm. For the same flight condition at maximum engine speed, the compressor efficiency was 78 percent.

When the altitude is increased from 5000 to 45,000 feet at any constant corrected engine speed above 5500 rpm, a decrease in compressor efficiency of approximately 5 percent resulted (fig. 7(a)). This change in compressor efficiency with altitude is attributed to the change in Reynolds number and is similar to the previously shown effect of altitude on the compressor air flow. The compressor efficiency curve for 15,000 feet altitude is below those for 25,000 and 35,000 feet over the upper range of engine speeds. However, unscheduled engine data for the same flight condition indicated that the curve should be about 2 percent higher over this range of speeds (fig. 3). It was therefore concluded that this discrepancy was caused by data error.

On the compressor performance maps, the constant speed lines and the efficiency contours are nearly parallel at high corrected engine speeds, and approximately perpendicular to each other at low engine speeds (fig. 3). Consequently, changes in compressor pressure ratio have little effect on efficiency at high engine speeds and a large effect at low speeds. Compressor efficiency therefore decreased with increased flight Mach number (decreasing compressor pressure ratio) at corrected engine speeds below 6000 rpm (fig. 7(b)). At corrected engine speeds above 7000 rpm, the efficiency increased slightly with increasing Mach number, probably because of the corresponding increase in compressor Reynolds number.

<u>Effect of Reynolds number on compressor performance</u>. - Shifts in the efficiency contours and corrected engine speed lines on compressor performance maps, with changes in flight conditions (fig. 3) have been attributed to changes in compressor Reynolds number. In order to show more clearly the effect of Reynolds number on compressor performance, cross plots (fig. 8), showing compressor corrected air flow and efficiency as functions of Reynolds number index, were made from the data in figures 5(b) and 7(a). For a given compressor Mach number (corrected engine speed), Reynolds number index varies linearly with Reynolds number and is defined as the ratio of Reynolds number at altitude to Reynolds number at standard sea-level conditions:

$$\frac{\delta}{\phi\sqrt{\theta}} = \frac{\dfrac{P}{P_{sl}}}{\dfrac{\mu}{\mu_{sl}}\sqrt{\dfrac{T}{T_{sl}}}}$$

The effect of Reynolds number index on efficiency was nearly the same at all values of engine speed (fig. 8(a)). The critical value of Reynolds number index was approximately 0.4. Changing Reynolds number index from 0.88 to 0.4 resulted in a decrease in compressor efficiency of only approximately 2.5 percent, whereas changing the index from 0.4 to 0.11 resulted in a decrease in efficiency of approximately 5 percent. 2307

There was no appreciable effect of Reynolds number on the corrected air flow in the range of values above critical (0.4) (fig. 8(b)). At values of Reynolds number index below critical, air flow decreased with Reynolds number index.

Combustors

Combustion efficiency. - With the original combustors installed and with the engine operating on the electronic control schedule, combustion efficiency increased with increasing corrected engine speed (fig. 9). At a given corrected engine speed, combustion efficiency decreased with an increase in altitude (fig. 9(a)) and increased with flight Mach number (fig. 9(b)). The effect of changes in altitude or flight Mach number was greater at lower engine speeds. Combustion efficiencies for corrected engine speeds below 4000 rpm were of questionable accuracy and therefore omitted from these plots.

Comparison of the data in figure 9 with similar data from previous investigations of the J47 turbojet engine (reference 5) shows that in the present investigation, combustion efficiency was more sensitive to changes in engine speed, altitude, and flight Mach number. This may be attributed to the increased air flow in the prototype J47D (RX1-1) turbojet engine resulting in higher combustor velocities than obtained with the earlier model of the turbojet engine at similar flight conditions.

During nonscheduled operation, changing the exhaust-nozzle area from maximum to minimum had little effect on combustion efficiency. At an altitude of 15,000 feet and a flight Mach number of 0.19, changing the nozzle position from full open to full closed resulted in a 1-percent increase in combustion efficiency when the corrected engine speed was maintained at 8310 rpm (fig. 10).

Comparison of the operating lines for the modified combustors (fig. 11) with those for the original combustors (fig. 9) shows that at engine speeds near rated the combustion efficiencies of the modified combustors were 1 or 2 percent higher. Also, the efficiency of the modified combustors did not reduce as rapidly with decreasing engine speed.

The effects of altitude, engine speed, and flight Mach number on combustion efficiency indicate that operating conditions that cause higher values of combustor-inlet pressure and temperature are conducive to higher values of combustion efficiency. This fact is apparent from correlation of combustion efficiency in terms of the combustor parameters P_3T_3/V_3 and fuel-air ratio f/a for both the original and modified combustors (fig. 12). The parameter P_3T_3/V_3 has been used to correlate the combustion efficiency of several combustors (reference 9). With this combustor, however, some spread with fuel-air ratio was obtained. For values of P_3T_3/V_3 above 12,000, the combustion efficiency was nearly constant for each combustor regardless of the value of the fuel-air ratio. At values of P_3T_3/V_3 below 12,000, combustion efficiency decreased with decreasing P_3T_3/V_3 and there was also a trend towards decreasing efficiency with decreasing fuel-air ratio at a given value of P_3T_3/V_3. For values of P_3T_3/V_3 above 12,000, the combustion efficiencies for the modified combustors are approximately 2 percent higher than the original combustors. For values of P_3T_3/V_3 below 12,000, the gain in efficiency obtained with the modified combustors increased with decreasing P_3T_3/V_3.

Combustor pressure drop. - From the momentum equation for gases passing through the combustors, the following equation may be derived (see appendix B):

$$\frac{P_3 - P_4}{q_b} \approx \frac{T_4}{T_3} - 1 + C_{D_f} \tag{1}$$

Data for various altitudes and flight Mach numbers are plotted to show $\frac{P_3 - P_4}{q_b}$ as a function of T_4/T_3 for both the original and modified combustors (fig. 13). From equation (1), when T_4/T_3 equals 1.0, $\frac{P_3 - P_4}{q_b}$ equals C_{D_f}. By extrapolating the data in figure 13 to T_4/T_3 equals 1.0, it is apparent that the friction-drag coefficients for the original and the modified burners are approximately 10.0 and 12.0, respectively. With these values of drag coefficient, the theoretical curves of $\frac{P_3 - P_4}{q_b} = T_4/T_3 - 1 + C_{D_f}$ were plotted in figure 13. Scatter of the data about these theoretical lines indicates fair agreement between the theoretical and the experimental values of combustor pressure drop (that is, the average slope of the data is approximately the same as the slope of the theoretical lines). Values of pressure drop based on the inlet total pressure $\frac{P_3 - P_4}{P_3}$ are presented in the tables. 2307

The improved combustion-efficiency characteristics and increased pressure loss obtained with the modified combustors are most likely due to improved fuel distribution and increased turbulence in the combustor caused by the addition of the baffles to the secondary air holes in the combustor liners.

Turbine

Engine on electronic control schedule. - Curves are presented in figure 14 that show the effect of altitude and corrected engine speed $N/\sqrt{\theta_1}$ on the parameters η_t, $\frac{T_4}{\theta_1}$, $\frac{N}{\sqrt{\theta_4}}$, $\frac{P_4}{P_6}$, and $\frac{W_{g,4}\sqrt{\theta_4}}{\delta_4 \, \gamma_4/1.4}$ when the engine is operating on the electronic control schedule. Data for corrected engine speed below 4000 rpm were omitted in these plots because of dubious accuracy.

For corrected engine speeds over 4000 rpm, the values of turbine efficiency were between 79 and 86 percent (fig. 14(a)). The effects of altitude and engine speed on efficiency were small over this speed range, and scatter of the data precludes determination of any definite trends. Corrected turbine-inlet temperature was not affected appreciably by increases in altitude up to 25,000 feet but increased with altitude above 25,000 feet (fig. 14(b)). This phenomenon was due to the Reynolds number effects on the compressor, which reduced compressor efficiency at higher altitudes so that an increase in turbine power was required to attain a given engine speed. The reduction in corrected turbine speed with altitude above 25,000 feet follows from the effect of altitude on corrected turbine-inlet temperature (fig. 14(c)). At a given corrected engine speed, the turbine pressure ratio was not appreciably affected by an increase in altitude up to 35,000 feet (fig. 14(d)). At higher altitudes, turbine pressure ratio decreased slightly with altitude. Although critical pressure ratios exist across the turbine at corrected engine speeds over 5000 rpm, there is a slight increase in corrected turbine gas flow with corrected engine speed in this range indicating that there may be changes in the effective turbine nozzle area (fig. 14(e)). The trend is small, however, compared with the amount of data scatter. Altitude has no discernible effect on the corrected turbine gas flow.

At a given corrected engine speed, neither variation of flight Mach number from 0.19 to 0.92 at an altitude of 25,000 feet nor variation of exhaust-nozzle area from maximum to minimum had any appreciable effect on turbine efficiency (tables I and II).

SUMMARY OF RESULTS

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The following results were obtained from an investigation of the performance of the components of a prototype J47D (RX1-1) turbojet engine in the NACA Lewis altitude wind tunnel:

1. For all flight conditions investigated, the peak compressor efficiency occurred in the range of corrected engine speeds between 6000 and 6500 rpm, which is below the specified engine cruising speed range. A maximum value of 86 percent was obtained at an altitude of 5000 feet, a flight Mach number of 0.19, and corrected engine speed of 6000 rpm. At the same flight condition, but at maximum speed, the efficiency was 78 percent.

2. At corrected engine speeds above 5500 rpm and a flight Mach number of 0.19, changing altitude from 5000 to 45,000 feet caused approximately a 5-percent reduction in compressor efficiency. Corrected air flow at constant corrected engine speeds was not affected by an increase in altitude up to 25,000 feet, but decreased when altitude was further increased. The reductions in compressor efficiency and corrected air flow with increasing altitude are attributed to corresponding reductions in compressor Reynolds number. Critical Reynolds number index for the compressor was of the order of 0.4.

3. At an altitude of 25,000 feet, changing flight Mach number from 0.19 to 0.92 had no effect on corrected air flow but resulted in a reduction in compressor efficiency at corrected engine speeds below 6000 rpm and a small increase in efficiency at corrected engine speeds above 7000 rpm.

4. Combustion efficiency increased with increasing corrected engine speed. At a given corrected engine speed the combustion efficiency increased with flight Mach number and decreased with an increase in altitude. These effects are probably due to the corresponding increases in combustor-inlet pressure and temperature.

5. At approximately rated engine speeds, the modified combustor gave combustion efficiencies 1 or 2 percent higher than the original combustors. Also, the efficiency of the modified combustor did not reduce as rapidly with decreasing engine speed.

6. It was possible to correlate combustion efficiency, for each combustor type, in terms of the fuel-air ratio and the parameter $\frac{P_3\,T_3}{V_3}$ where P_3, T_3, and V_3 are the stagnation pressure, stagnation temperature, and velocity, respectively, at the combustor inlet. Also, combustor pressure-drop parameter $\frac{P_3 - P_4}{q_b}$ where P_3 is the stagnation pressure at the combustor inlet, P_4 is the stagnation pressure at the turbine, and q_b is the theoretical dynamic pressure at the combustor inlet, was correlated in terms of combustor temperature ratio. Friction drag coefficients of the original and modified combustors were 10.0 and 12.0, respectively.

7. At corrected engine speeds over 4000 rpm, the turbine efficiency values were between 79 and 86 percent for altitudes from 5000 to 55,000 feet with a flight Mach number of 0.19. Variation of exhaust-nozzle area, or of flight Mach number from 0.19 to 0.92 had no appreciable effect on turbine efficiency.

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APPENDIX A

Symbols

The following symbols were used in this report:

A	cross-sectional area, sq ft
C_{D_f}	combustor friction drag coefficient
f/a	fuel-air ratio
g	acceleration due to gravity, 32.2 ft/sec^2
M	Mach number
m	mass flow, slugs/sec
N	engine speed, rpm
P	stagnation pressure, lb/sq ft abs.
p	static pressure, lb/sq ft abs.
q_b	theoretical dynamic pressure at combustor inlet; calculated using stagnation pressure, stagnation temperature, and air flow at station 3, combustor cross-sectional area (3.85 sq ft), and $\gamma = 1.4$.
R	gas constant, 53.4 ft-lb/(lb)($^\circ$R)
T	stagnation temperature, $^\circ$R
V	velocity, ft/sec
W_a	air flow, lb/sec
W_f	fuel flow, lb/hr
W_g	gas flow, lb/sec
γ	ratio of specific heats
δ	pressure correction factor, $\frac{\text{stagnation pressure}}{\text{NACA standard sea-level pressure}}$, P/2116

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η adiabatic efficiency

ρ density, slugs/cu ft

μ absolute viscosity, lb-sec/ft^2

θ temperature correction factor, product of γ and stagnation temperature divided by product of γ and temperature at NACA standard sea-level conditions $\frac{\gamma T}{(1.4)(519)}$

ϕ viscosity correction factor, $\frac{\text{air viscosity}}{\text{air viscosity with NACA standard sea-level temperature}}$, $\frac{\mu}{\mu_0}$

Corrected parameters:

$N/\sqrt{\theta_1}$ corrected engine speed, rpm

$N/\sqrt{\theta_4}$ corrected turbine speed, rpm

T_4/θ_1 corrected turbine-inlet temperature, $^{\circ}R$

$\frac{W_{a,1}\sqrt{\theta_1}}{\delta_1}$ corrected compressor air flow, lb/sec

$\frac{W_{g,4}\sqrt{\theta_4}}{\delta_4\ \gamma_4/1.4}$ corrected turbine gas flow, lb/sec

Subscripts:

a air

b burner

c compressor

g gas

sl sea level

t turbine

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0	ambient
1	compressor inlet
3	compressor discharge, combustor inlet
4	combustor discharge, turbine inlet
6	turbine discharge
8	exhaust-nozzle inlet

APPENDIX B

CALCULATIONS

Air flow. - The air flow at station 1 was calculated from pressure and temperature measurements by use of the equation 2307

$$W_{a,1}' = g\rho_1 A_1 V_1 = p_1 A_1 \sqrt{\frac{2\,\gamma_1\, g}{(\gamma_1 - 1)Rt_1}\left[\left(\frac{P_1}{p_1}\right)^{\frac{\gamma_1 - 1}{\gamma}} - 1\right]} \tag{B1}$$

where $\gamma_1 = 1.4$.

Starter-cooling $W_{s,c}$, compressor-leakage $W_{c,1}$, and turbine-cooling $W_{t,c}$ air flows were calculated from pressure and temperature measurements assuming incompressible flow. The starter-cooling air is ram air inducted through a hole in the starter fairing and discharged into the engine inlet aft of station 1. Compressor-leakage air is dumped overboard, and turbine-cooling air is bled from the eighth stage of the compressor and returned to the main airstream at the turbine. The air and gas flows at various stations through the engine were calculated as follows:

Compressor-inlet air flow, $W_{a,1} = W_{a,1}' + W_{s,c}$ (B2)

Compressor-discharge air flow, $W_{a,3} = W_{a,1} - W_{c,1} - W_{t,c}$ (B3)

Combustor-discharge gas flow, $W_{g,4} = W_{a,3} + W_f$ (B4)

Combustor pressure loss. - The expression for combustor pressure loss is derived as follows:

It is assumed:

(1) The fluid flow in the combustor is incompressible.

(2) In the following figure, $P_b = P_3$, $P_x = P_4$, $T_b = T_3$, $T_x = T_4$.

(3) The burning area between stations b and x is constant $(A_b = A_x)$.

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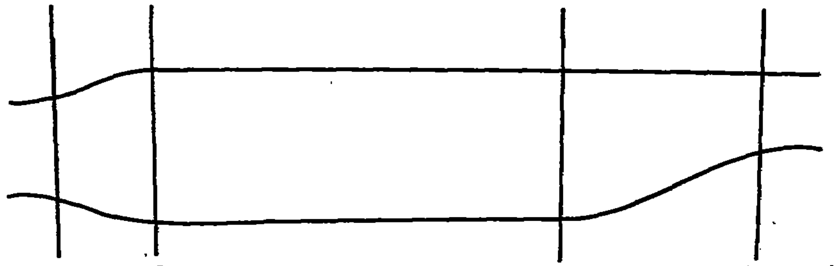

The momentum equation yields

$$p_bA_b + m_bV_b = p_xA_b + m_xV_x + C_{D_f} A_b q_b$$

$$p_bA_b + A_b\rho_bV_b{}^2 = p_xA_b + A_b \rho_bV_x{}^2 + C_{D_f} A_b q_b$$

$$p_bA_b + 2A_b q_b = p_xA_b + 2A_b q_x + C_{D_f} A_b q_b \tag{B5}$$

$$P_bA_b + q_b A_b = P_x A_b + q_xA_b + C_{D_f} A_b q_b$$

Dividing by q_bA_b and transposing yields

$$\frac{P_b - P_x}{q_b} = \frac{q_x}{q_b} - 1 + C_{D_f} \tag{B6}$$

If

$$\frac{P_x}{P_b} \cong 1.0$$

then

$$\frac{P_b - P_x}{q_b} \cong \frac{T_x}{T_b} - 1 + C_{D_f}$$

or

$$\frac{P_3 - P_4}{q_b} \cong \frac{T_4}{T_3} - 1 + C_{D_f} \tag{B7}$$

Combustor-reference dynamic pressure. - In order to calculate a combustor-reference dynamic pressure, based on the total combustor cross-sectional area (3.85 sq ft), a combustor-reference Mach number was first calculated with the equation

$$\frac{M_b}{\left(1 + \frac{\gamma_3 - 1}{2} M_b^{\,2}\right)^{\frac{\gamma_3+1}{2(\gamma_3-1)}}} = \frac{W_{a,3}\sqrt{T_3}}{0.776\ A_b\ P_3\ \gamma_3} \tag{B8}$$

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Then

$$q_b = \frac{\gamma_3}{2}\ p_b\ M_b^{\,2}$$

and

$$p_b = \frac{P_3}{\left(1 + \frac{\gamma_3 - 1}{2} M_b^{\,2}\right)^{\frac{\gamma_3}{\gamma_3-1}}}$$

therefore

$$q_b = \frac{\gamma_3}{2}\ P_3 \frac{M_b^{\,2}}{\left(1 + \frac{\gamma_3 - 1}{2} M_b^{\,2}\right)^{\frac{\gamma_3}{\gamma_3-1}}} \tag{B9}$$

where $\gamma_3 = 1.40$

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TABLE I - COMPONENT PERFORMANCE OF PROTOTYPE J47D (RX1-1) TURBOJET

Run	Altitude (ft)	Tunnel static pressure, P_0 (lb/sq ft abs.)	Ram pressure ratio P_1/P_0	Flight Mach number M	Engine speed N (rpm)	Fuel flow W_f (lb/hr)	Exhaust-nozzle outlet area (sq ft)	Compressor-inlet stagnation temperature, T_1 (°R)	Compressor-inlet stagnation pressure, P_1 (lb/sq ft abs.)	Compressor-discharge stagnation pressure P_3 (lb/sq ft abs.)	Compressor-discharge stagnation temperature T_3 (°R)	Turbine-inlet stagnation temperature T_4 (°R)	Turbine-inlet stagnation pressure P_4 (lb/sq ft abs.)	Turbine-discharge stagnation pressure P_6 (lb/sq ft abs.)	Nozzle-inlet stagnation temperature T_8 (°R)	Compressor pressure ratio P_3/P_1
1	5000	1747	1.021	0.173	7955	5315	2.31	504	1784	9450	897	2050	9098	3604	1711	5.295
2		1764	1.021	.173	7955	4770	2.39	505	1801	9289	892	1940	8913	3415	1600	5.155
3		1761	1.021	.173	7955	4485	2.45	503	1798	9206	886	1870	8773	3270	1533	5.12
4		1757	1.022	.176	7955	4235	2.56	504	1796	9080	882	1825	8642	3176	1486	5.06
5		1754	1.021	.173	7692	3790	2.56	504	1791	8613	859	1729	8242	3041	1408	4.81
6		1754	1.023	.180	7386	3340	2.57	507	1794	8261	833	1615	7855	2892	1320	4.60
7		1749	1.023	.180	6993	2860	2.61	504	1790	7594	809	1520	7204	2708	1239	4.24
8		1756	1.027	.195	5944	1675	2.91	505	1804	5683	732	1250	5348	2221	1036	3.14
9		1766	1.025	.188	5114	1227	2.94	504	1811	4363	677	1155	4120	2037	995	2.41
10		1772	1.033	.216	4091	1020	2.94	504	1830	3086	610	1165	2942	1931	1067	1.69
11		1759	1.028	.199	3147	823	2.94	504	1809	2401	584	1190	2318	1851	1129	1.33
12		1759	1.028	.199	2046	515	2.94	501	1809	1990	526	1125	1959	1808	1100	1.10
13	15,000	1192	1.023	0.180	7955	3960	2.28	472	1220	6872	871	2058	6557	2564	1728	5.63
14		1188	1.023	.180	7955	3500	2.39	473	1215	6611	870	1965	6310	2395	1623	5.44
15		1191	1.023	.180	7955	3100	2.55	473	1218	6412	866	1855	5116	2233	1509	5.26
16		1188	1.026	.192	7692	2890	2.55	473	1219	6084	839	1713	5807	2121	1386	4.995
17		1189	1.024	.184	6993	1975	2.63	472	1217	5517	782	1470	5064	1895	1191	4.37
18		1194	1.027	.195	5944	1185	2.91	474	1226	4066	707	1205	3844	1554	985	3.32
19		1190	1.027	.195	5114	870	2.91	472	1222	3112	651	1112	2940	1401	946	2.55
20		1189	1.028	.199	4091	758	2.91	472	1222	2161	585	1108	2061	1311	1002	1.77
21		1191	1.029	.203	3147	635	2.91	475	1225	1662	537	1130	1602	1247	1067	1.36
22		1190	1.029	.203	2448	518	2.91	472	1224	1461	509	1112	1430	1234	1081	1.19
23	25,000	782	1.024	0.184	7955	2730	2.28	480	801	4605	878	2102	4587	1726	1746	5.75
24		781	1.023	.180	7955	2675	2.31	461	799	4586	877	2102	4565	1726	1742	5.74
25		781	1.023	.180	7955	2380	2.40	463	799	4401	864	1970	4199	1606	1619	5.51
26		783	1.023	.180	7955	2270	2.45	465	801	4327	874	1916	4158	1556	1552	5.40
27		782	1.023	.180	7955	2150	2.53	464	800	4285	853	1860	4080	1498	1515	5.35
28		784	1.022	.176	7692	1875	2.58	463	801	4073	832	1720	3888	1425	1390	5.08
29		782	1.024	.184	6993	1385	2.61	463	801	3572	774	1481	3405	1280	1198	4.46
30		781	1.024	.184	5944	850	2.89	465	800	2727	695	1203	2580	1038	980	3.42
31		781	1.027	.195	5114	645	2.94	464	802	2070	639	1102	1957	941	937	2.58
32		783	1.028	.199	4091	570	2.94	465	805	1425	577	1100	1361	867	993	1.77
33		780	1.032	.212	2048	300	2.94	466	805	913	496	1101	897	816	1073	1.14
34		774	1.198	.515	7955	3065	2.23	465	927	5301	874	2077	5087	1959	1722	5.72
35		772	1.198	.515	7955	3065	2.23	466	925	5267	865	2041	5032	1948	1698	5.68
36		777	1.190	.505	7955	2590	2.42	466	925	5042	856	1902	4804	1785	1554	5.45
37		774	1.193	.509	7955	2330	2.55	466	923	4869	850	1790	4635	1651	1440	5.28
38		775	1.192	.507	7692	2010	2.58	464	924	4624	824	1639	4404	1560	1315	5.00
39		776	1.201	.519	6993	1445	2.62	463	932	4093	766	1408	3896	1396	1127	4.39
40		776	1.202	.520	5944	759	2.89	463	935	3064	687	1089	2884	1093	870	3.28
41		779	1.204	.522	5114	512	2.93	463	938	2304	632	954	2159	965	788	2.46
42		781	1.195	.511	4091	421	2.93	463	933	1576	566	889	1486	870	788	1.69
43		776	1.397	.708	7955	3405	2.23	467	1084	6056	863	2020	5793	2225	1677	5.58
44		774	1.397	.708	7955	2885	2.42	471	1081	5766	861	1869	5497	2018	1523	5.34
45		782	1.391	.704	7955	2545	2.55	472	1088	5611	855	1750	5290	1864	1405	5.15
46		781	1.394	.706	7692	2170	2.55	473	1089	5306	828	1609	5054	1747	1295	4.87
47		779	1.401	.711	6993	1520	2.60	474	1091	4630	775	1368	4402	1549	1090	4.24
48		782	1.391	.704	5944	877	2.91	475	1088	3547	693	1022	3137	1137	808	3.07
49		781	1.399	.710	5114	376	2.93	475	1093	2435	632	854	2268	966	695	2.23
50		779	1.403	.713	4091	241	2.93	466	1093	1701	562	734	1593	887	638	1.57
51		786	1.732	.922	7955	3840	2.14	509	1361	7108	904	2010	6766	2661	1668	5.22
52		782	1.730	.921	7955	3705	2.26	512	1353	6977	905	1993	6669	2596	1645	5.15
53		779	1.720	.916	7955	3150	2.37	504	1340	6705	888	1825	6398	2343	1482	5.00
54		786	1.734	.923	7955	2955	2.45	511	1363	6654	891	1758	6338	2259	1426	4.88
55		779	1.736	.924	7955	2775	2.53	504	1352	6592	878	1710	6246	2163	1372	4.87
56		788	1.731	.922	7692	2485	2.53	508	1364	6250	860	1611	5938	2045	1290	4.58
57		781	1.730	.921	6993	1564	2.63	505	1351	5326	800	1332	5036	1707	1056	3.94
58		784	1.727	.920	5944	573	2.91	510	1354	3742	720	968	3479	1209	781	2.76
59		779	1.734	.923	5280	277	2.91	501	1361	2873	659	793	2660	1024	635	2.13
60	35,000	498	1.020	0.169	7955	1720	2.38	458	508	2906	866	2070	2768	1059	1715	5.74
61		494	1.020	.169	7955	1695	2.4	454	504	2891	863	2049	2751	1052	1699	5.74
62		498	1.020	.169	6993	968	2.63	451	508	2337	761	1490	2231	825	1209	4.60
63		498	1.022	.176	5944	615	2.89	452	509	1781	684	1208	1688	687	985	3.50
64		494	1.028	.199	5114	490	2.93	451	508	1302	625	1100	1235	594	930	2.56
65		494	1.034	.219	4091	480	2.93	451	511	968	559	1109	926	548	1009	1.89
66	45,000	308	1.039	0.235	7955	1130	2.475	448	320	1834	867	2059	1746	657	1702	5.73
67		310	1.023	.180	7955	1088	2.56	447	317	1808	860	2036	1729	645	1681	5.70
68		303	1.026	.192	7955	1036	2.56	445	311	1771	855	2010	1687	626	1659	5.35
69		310	1.032	.212	7955	1020	2.61	445	320	1800	857	2005	1718	628	1648	5.53
70		303	1.026	.192	7692	890	2.58	446	311	1645	829	1871	1573	583	1538	5.29
71		310	1.026	.192	7386	768	2.58	447	318	1593	800	1728	1514	577	1415	5.01
72		301	1.027	.190	7386	780	2.61	451	309	1544	805	1736	1475	556	1422	5.00
73		306	1.033	.216	6993	689	2.62	447	316	1471	769	1585	1406	541	1294	4.65
74		311	1.026	.192	5944	475	2.855	451	319	1127	693	1280	1071	440	1080	3.53
75		310	1.032	.212	5114	392	2.94	450	320	829	631	1160	789	380	991	2.59
76		310	1.029	.200	5114	392	2.94	449	319	834	630	1160	794	387	989	2.61
77	55,000	190	1.032	.212	7955	859	2.66	453	196	1076	872	2041	1039	380	1682	5.49
78		191	1.026	.192	7955	647	2.63	456	196	1091	867	2051	1048	378	1695	5.57
79		190	1.032	.212	7955	635	2.705	453	196	1087	876	2038	1039	381	1677	5.55
80		190	1.037	.228	7692	645	2.58	454	197	1048	853	1999	1001	370	1657	5.33
81		189	1.032	.212	6993	541	2.61	454	195	898	799	1780	861	341	1476	4.80

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ENGINE ON ELECTRONIC CONTROL SCHEDULE - ORIGINAL COMBUSTORS INSTALLED

Air flow $W_{a,1}$ (lb/sec)	Corrected engine speed, $N/\sqrt{\theta_1}$ (rpm)	Corrected air flow $\frac{W_{a,1}\sqrt{\theta_1}}{\delta_1}$ (lb/sec)	Compressor efficiency η_c (percent)	Burner combustion parameter $\frac{P_3T_3}{V_3}$	Combustion efficiency η_b (percent)	Burner pressure-loss coefficient $\frac{P_3-P_4}{q_b}$	Fuel-air ratio f/a	Combustion-chamber stagnation-temperature ratio, T_4/T_3	Burner pressure loss $\frac{P_3-P_4}{P_3}$	Turbine pressure ratio P_4/P_6	Turbine efficiency η_t (percent)	Corrected turbine-inlet temperature T_4/θ_1 (°R)	Corrected turbine speed, $N/\sqrt{\theta_4}$ (rpm)	Corrected turbine gas flow $\frac{W_{g,4}\sqrt{\theta_1}}{\delta_4\gamma_0/1.4}$ (lb/sec)	Run
85.69	8074	99.87	78.3	30,371	96.1	9.62	0.0177	2.285	0.038	2.524	82.7	2111	4135	40.56	1
86.87	8066	100.66	78.1	27,629	98.0	9.88	.0156	2.175	.041	2.610	83.8	1994	4240	40.68	2
86.86	8082	100.62	78.2	24,465	96.8	11.19	.0147	2.111	.047	2.683	83.3	1930	4314	40.54	3
86.19	8074	100.18	78.6	23,431	97.0	11.48	.0140	2.069	.048	2.721	84.3	1880	4364	40.29	4
85.04	7807	99.17	80.5	24,321	97.1	9.58	.0127	2.013	.043	2.710	83.7	1781	4326	40.44	5
83.46	7475	97.25	85.2	20,715	98.6	10.91	.0114	1.939	.049	2.718	81.1	1654	4289	40.14	6
79.37	7098	92.48	84.6	18,770	97.4	10.94	.0102	1.879	.051	2.660	82.8	1566	4177	40.25	7
64.78	8027	74.94	88.1	12,810	95.6	10.90	.0073	1.708	.056	2.408	81.8	1285	3890	39.83	8
50.64	5191	58.30	85.3	9,612	93.1	11.37	.0069	1.706	.056	2.023	79.9	1190	3474	38.83	9
36.07	4152	41.05	76.6	7,006	92.7	10.38	.0080	1.910	.047	1.524	78.8	1200	2768	38.98	10
26.41	3194	30.44	70.8	6,119	94.6	9.35	.0088	2.110	.035	1.252	88.3	1226	2109	36.74	11
17.87	2083	20.54	57.6	6,815	98.0	8.78	.0081	2.143	.016	1.084	104.2	1165	1407	28.54	12
61.09	8345	100.98	77.7	19,866	95.4	12.72	0.0185	2.374	0.046	2.557	81.4	2275	4120	40.38	13
60.51	8329	100.68	74.3	18,482	96.5	11.67	.0165	2.259	.046	2.635	82.8	2156	4218	40.35	14
61.02	8329	101.23	73.2	17,091	98.2	11.00	.0145	2.142	.046	2.739	84.9	2035	4333	40.69	15
60.42	8054	100.18	75.6	15,726	97.5	10.34	.0127	2.044	.046	2.738	85.2	1879	4348	40.65	16
56.85	7336	94.24	79.9	12,921	95.7	9.92	.0099	1.880	.048	2.672	84.4	1617	4243	40.37	17
47.34	6217	78.12	83.2	8,928	94.8	10.50	.0071	1.704	.055	2.474	84.5	1519	3957	39.79	18
37.15	5365	61.34	80.8	6,724	92.8	11.06	.0066	1.708	.055	2.099	80.1	1223	3537	39.14	19
25.69	4291	42.42	73.9	4,875	83.4	10.29	.0083	1.894	.046	1.572	83.2	1219	2833	38.64	20
18.34	3289	30.31	69.9	3,904	79.5	10.81	.0098	2.104	.036	1.285	86.1	1235	2161	35.8	21
13.67	2568	22.53	63.5	4,272	74.8	6.04	.0107	2.185	.015	1.159	72.1	1225	1694	29.76	22
40.40	8448	101.75	71.4	11,857	95.3	12.78	0.0191	2.394	0.047	2.542	84.6	2371	4088	40.70	23
40.55	8440	101.20	71.8	11,801	96.6	13.39	.0188	2.397	.048	2.529	85.9	2367	4088	40.54	24
40.44	8424	101.12	72.6	11,890	96.2	11.77	.0168	2.280	.046	2.615	85.4	2208	4213	40.60	25
40.48	8400	101.28	70.5	11,590	95.0	9.54	.0160	2.192	.039	2.672	88.7	2136	4268	40.43	26
40.46	8416	101.15	73.5	11,534	96.1	11.95	.0151	2.181	.048	2.724	84.4	2081	4326	40.52	27
39.89	8146	99.52	74.5	10,491	94.5	10.56	.0134	2.067	.045	2.728	86.0	1928	4338	40.17	28
38.30	7406	95.55	79.4	8,634	94.9	9.75	.0103	1.913	.047	2.660	85.3	1660	4228	40.64	29
31.81	6277	79.88	84.9	5,864	89.6	10.57	.0076	1.731	.054	2.486	85.4	1343	3963	39.84	30
24.98	5411	62.28	82.6	4,484	84.1	10.92	.0073	1.725	.055	2.080	83.0	1233	3551	39.36	31
15.88	4320	39.53	73.6	3,147	69.1	11.51	.0101	1.908	.045	1.570	85.1	1228	2845	36.19	32
8.20	2159	20.43	56.8	2,736	76.7	8.33	.0104	2.220	.018	1.099	101.6	1227	1423	28.18	33
47.28	8400	102.22	73.5	13,993	98.0	11.92	.0185	2.376	.044	2.587	83.8	2318	4111	40.48	34
46.64	8393	101.15	75.3	14,237	92.9	12.39	.0187	2.360	.045	2.583	82.3	2274	4145	39.86	35
46.39	8393	100.61	74.6	13,362	95.4	12.10	.0159	2.222	.047	2.691	84.7	2119	4284	39.93	36
46.26	8393	100.54	73.9	12,676	94.4	11.73	.0143	2.106	.048	2.807	86.2	1994	4405	39.94	37
46.16	8138	99.91	75.4	11,848	92.7	10.82	.0124	1.989	.046	2.823	85.2	1834	4436	39.98	38
43.74	7406	93.76	80.5	9,707	93.8	10.23	.0094	1.838	.048	2.791	84.7	1578	4330	39.42	39
37.10	6295	79.45	83.7	6,632	91.8	10.87	.0058	1.585	.059	2.639	86.4	1221	4151	39.40	40
29.62	5416	63.10	80.3	4,565	85.0	11.23	.0049	1.509	.063	2.237	86.9	1069	3799	39.20	41
21.27	4332	45.55	72.7	3,024	74.5	10.20	.0056	1.571	.057	1.708	82.3	997	3147	39.58	42
53.80	8385	102.25	75.0	17,716	96.4	11.42	.0176	2.341	.043	2.604	82.2	2244	4165	40.73	43
53.19	8385	101.60	74.2	15,327	96.5	11.39	.0151	2.171	.047	2.724	84.4	2060	4316	40.59	44
53.48	8545	101.51	73.8	14,441	97.2	13.30	.0132	2.047	.057	2.838	85.7	1925	4456	40.40	45
53.03	8054	100.62	76.3	13,444	96.7	10.35	.0114	1.943	.048	2.893	82.0	1765	4475	40.48	46
49.80	7315	94.29	80.6	10,913	95.0	9.84	.0085	1.765	.049	2.842	84.4	1498	4387	39.91	47
41.62	6211	78.81	82.6	6,945	96.5	10.45	.0046	1.475	.063	2.759	85.8	1117	4276	39.44	48
32.96	5344	61.99	77.9	4,627	91.7	10.55	.0032	1.351	.069	2.348	87.6	933	4008	39.76	49
24.34	4316	45.25	65.4	2,986	78.4	9.92	.0027	1.306	.064	1.796	85.9	818	3449	38.64	50
65.31	8035	100.55	77.9	19,638	96.5	11.75	.0168	2.223	.048	2.543	84.1	2050	4174	41.10	51
64.73	8011	100.53	78.0	19,579	97.7	10.78	.0163	2.202	.044	2.569	85.1	2021	4189	41.14	52
64.66	8074	100.59	76.8	18,360	97.0	10.41	.0139	2.055	.046	2.731	85.0	1880	4364	40.82	53
64.90	8019	99.93	77.2	17,735	95.5	10.56	.0130	1.925	.047	2.806	82.3	1786	4442	40.52	54
65.46	8074	100.93	77.2	16,126	97.8	11.41	.0121	1.848	.053	2.888	84.1	1761	4499	40.84	55
64.47	7777	98.91	78.7	15,712	96.2	10.18	.0110	1.873	.050	2.904	83.5	1646	4472	40.95	56
59.86	7091	92.45	82.2	12,290	98.6	10.09	.0074	1.665	.055	2.950	82.9	1369	4440	40.39	57
48.81	5997	78.61	82.0	7,589	100.0	10.65	.0033	1.344	.070	2.878	84.0	985	4383	40.24	58
40.35	5375	62.07	78.4	5,359	91.7	10.59	.0019	1.203	.074	2.598	84.4	822	4286	39.25	59
25.81	8488	100.7	71.9	7,328	93.1	13.19	0.0191	2.390	0.048	2.614	83.3	2356	4117	40.35	60
25.61	8504	100.6	71.9	7,190	92.7	13.44	.0189	2.374	.048	2.615	82.7	2342	4139	40.04	61
24.45	7503	94.91	79.6	5,675	89.6	10.09	.0112	1.958	.045	2.704	83.1	1715	4218	39.76	62
20.31	6366	78.83	83.9	3,945	81.6	10.88	.0086	1.766	.052	2.531	83.6	1387	3955	39.01	63
15.81	5487	61.37	80.1	2,789	72.3	10.30	.0088	1.760	.052	2.079	86.0	1279	3556	39.61	64
11.04	4390	42.61	83.7	2,205	59.9	11.13	.0123	1.984	.043	1.690	68.7	1276	2835	37.23	65
16.19	8560	99.50	69.2	4,692	88.5	13.35	0.0199	2.375	0.048	2.658	82.9	2384	4130	40.06	66
16.16	8568	100.16	69.9	4,667	90.4	12.14	.0192	2.367	.044	2.681	82.3	2364	4150	40.06	67
15.70	8591	98.91	70.0	4,499	90.4	13.17	.0188	2.351	.047	2.895	81.9	2344	4174	39.69	68
16.25	8591	99.50	69.0	4,579	94.0	12.32	.0179	2.340	.046	2.736	82.3	2338	4180	40.26	69
15.70	8300	99.00	71.1	4,354	93.7	10.95	.0161	2.257	.044	2.698	82.0	2178	4174	41.02	70
15.56	7955	96.13	74.1	4,271	94.5	12.10	.0140	2.160	.050	2.624	84.2	2006	4156	40.41	71
14.96	7925	95.48	74.4	4,026	89.7	11.18	.0148	2.157	.045	2.653	83.4	1998	4149	40.03	72
14.99	7531	93.20	76.7	3,805	87.9	10.28	.0130	2.061	.044	2.599	84.8	1840	4099	40.00	73
12.13	6378	74.98	81.0	2,542	71.9	11.56	.0111	1.847	.050	2.434	81.9	1473	3850	37.91	74
9.77	5492	60.16	77.8	1,784	63.2	10.28	.0113	1.838	.048	2.076	81.7	1337	3469	39.53	75
10.23	5498	63.12	78.5	1,869	66.1	9.41	.0108	1.841	.048	2.052	83.9	1341	3469	41.13	76
9.57	8520	96.50	67.9	3,638	88.3	9.30	0.0196	2.431	0.034	2.734	81.8	2339	4148	39.66	77
9.51	8488	96.26	70.3	3,256	90.3	11.26	.0194	2.366	.039	2.772	79.8	2334	4135	39.11	78
9.57	8520	96.50	67.7	3,049	90.5	12.28	.0190	2.326	.044	2.727	82.4	2336	4150	39.58	79
9.29	8223	93.33	69.8	2,948	85.5	12.80	.0198	2.343	.045	2.705	80.0	2285	4048	39.52	80
8.60	7476	87.29	72.1	2,528	78.5	10.56	.0180	2.228	.041	2.525	83.5	2035	3887	40.01	81

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TABLE II - COMPONENT PERFORMANCE OF PROTOTYPE J47D (RX1-1) TURBOJET ENGINE;

Run	Altitude (ft)	Tunnel static pressure, p_0 (lb/sq ft abs.)	Ram pressure ratio P_1/p_0	Flight Mach number M	Engine speed N (rpm)	Fuel flow W_f (lb/hr)	Exhaust-nozzle outlet area (sq ft)	Compressor-inlet stagnation temperature, T_1 (°R)	Compressor-inlet stagnation pressure, P_1 (lb/sq ft abs.)	Compressor-discharge stagnation pressure P_3 (lb/sq ft abs.)	Compressor-discharge stagnation temperature T_3 (°R)	Turbine-inlet stagnation temperature T_4 (°R)	Turbine-inlet stagnation pressure P_4 (lb/sq ft abs.)	Turbine-discharge stagnation pressure P_6 (lb/sq ft abs.)	Nozzle-inlet stagnation temperature, T_8 (°R)	Compressor pressure ratio, P_3/P_1
1	15,000	1187	1.020	0.189	7955	3895	2.26	479	1211	6741	879	2078	6446	2531	1732	5.57
2		1186	1.024	.184	7955	3660	2.36	478	1215	6644	874	2022	6338	2468	1676	5.47
3		1191	1.023	.180	7955	3605	2.39	473	1218	6671	869	1992	6357	2433	1650	5.48
4		1188	1.024	.184	7955	3265	2.50	474	1217	6489	868	1909	6186	2294	1563	5.33
5		1192	1.023	.180	7955	3015	2.58	475	1220	6375	862	1819	6076	2180	1475	5.22
6		1188	1.025	.188	7955	2800	2.75	474	1218	6259	857	1749	5926	2070	1405	5.14
7		1190	1.022	.176	7955	2585	3.19	475	1216	6131	853	1675	5828	1921	1338	5.04
8		1188	1.024	.184	7386	3375	2.14	477	1216	6279	835	1940	6013	2494	1627	5.16
9		1190	1.024	.184	7386	3060	2.23	478	1219	6126	826	1828	5866	2361	1521	5.03
10		1190	1.023	.180	7386	2920	2.26	477	1217	6077	821	1780	5816	2292	1470	4.99
11		1187	1.024	.184	7386	2545	2.42	477	1215	5854	817	1657	5591	2108	1351	4.82
12		1186	1.024	.184	7386	2225	2.70	476	1215	5668	809	1550	5400	1945	1248	4.66
13		1188	1.024	.184	7386	1955	3.19	478	1217	5513	805	1468	5246	1794	1166	4.53
14		1185	1.026	.192	6643	2585	2.14	480	1214	5380	780	1715	5152	2221	1447	4.43
15		1186	1.026	.192	6643	2525	2.29	476	1217	5279	775	1613	5038	2089	1345	4.34
16		1186	1.024	.184	6643	2090	2.39	475	1215	5168	766	1524	4927	1983	1258	4.26
17		1188	1.024	.184	6643	1950	2.50	477	1217	5078	765	1471	4834	1889	1208	4.17
18		1190	1.024	.184	6643	1710	2.70	479	1219	4975	758	1378	4725	1782	1121	4.08
19		1192	1.024	.184	6643	1500	3.19	479	1221	4809	754	1303	4554	1651	1048	3.94
20		1193	1.027	.195	5944	1920	2.14	477	1225	4480	730	1524	4254	1943	1293	3.64
21		1188	1.026	.192	5944	1757	2.26	475	1219	4380	723	1453	4172	1851	1228	3.59
22		1191	1.025	.188	5944	1590	2.36	476	1221	4266	717	1379	4055	1767	1157	3.49
23		1190	1.025	.188	5944	1445	2.70	476	1220	4186	712	1318	3971	1689	1095	3.43
24		1190	1.026	.192	5944	1248	2.75	476	1221	4069	709	1230	3850	1570	1009	3.33
25		1187	1.027	.195	5944	1131	3.19	477	1219	3981	704	1185	3763	1518	964	3.27
26		1187	1.028	.199	5114	1501	2.14	474	1220	3316	660	1330	3164	1641	1165	2.72
27		1188	1.030	.206	5114	1214	2.26	473	1224	3288	659	1280	3121	1577	1109	2.69
28		1189	1.027	.195	5114	1102	2.45	473	1221	3249	660	1214	3082	1531	1047	2.66
29		1190	1.027	.195	5114	1053	2.55	474	1222	3179	652	1172	3016	1482	1015	2.60
30		1190	1.027	.195	5114	968	2.70	474	1222	3153	648	1150	2984	1453	984	2.58
31		1190	1.018	.160	5114	897	3.19	473	1211	3170	650	1105	2995	1389	936	2.62
32		1190	1.030	.206	4091	941	2.14	472	1226	2243	588	1252	2150	1404	1151	1.83
33		1186	1.029	.203	4091	938	2.26	469	1220	2250	585	1202	2155	1402	1131	1.84
34		1188	1.029	.203	4091	872	2.39	471	1223	2183	583	1185	2096	1368	1083	1.79
35		1188	1.029	.203	4091	836	2.47	471	1223	2183	582	1150	2083	1340	1052	1.79
36		1187	1.032	.212	4091	793	2.68	472	1228	2166	580	1112	2067	1325	1017	1.77
37		1182	1.031	.210	4091	758	2.93	472	1219	2142	582	1102	2041	1303	999	1.76
38		1190	1.029	.203	4091	758	3.19	471	1224	2136	579	1088	2036	1297	988	1.75
39	45,000	317	1.022	0.176	7955	1139	2.45	443	324	1847	859	2062	1773	794	1715	5.70
40		313	1.022	.176	7955	1010	2.55	443	320	1775	850	1973	1706	726	1627	5.54
41		313	1.016	.152	7955	933	2.63	442	318	1711	838	1885	1645	680	1639	5.38
42		303	1.026	.192	7955	866	2.77	443	311	1658	831	1825	1590	623	1489	5.33
43		303	1.030	.206	7955	812	3.18	443	312	1620	823	1770	1563	584	1436	5.18
44		310	1.032	.212	7386	1049	2.29	438	320	1757	818	1986	1674	677	1663	5.49
45		310	1.026	.192	7386	950	2.39	441	318	1691	809	1909	1618	639	1587	5.32
46		310	1.029	.203	7386	890	2.395	438	319	1648	800	1839	1577	618	1524	5.07
47		310	1.029	.203	7386	825	2.50	437	319	1597	791	1738	1531	574	1423	5.00
48		310	1.029	.203	7386	815	2.50	436	319	1633	795	1740	1569	584	1423	5.12
49		304	1.026	.192	7386	775	2.60	436	312	1585	787	1682	1506	552	1377	5.08
50		303	1.030	.206	7386	775	2.63	438	312	1572	788	1670	1497	551	1367	5.04
51		306	1.033	.216	7386	672	3.19	440	316	1518	784	1567	1446	504	1259	4.81
52		308	1.209	.203	6993	1042	2.14	441	317	1697	798	2010	1627	707	1705	5.35
53		307	1.026	.192	6993	950	2.23	443	315	1633	791	1921	1563	664	1619	5.19
54		307	1.029	.203	6993	734	2.45	441	316	1491	767	1619	1426	549	1327	4.72
55		304	1.030	.206	6993	684	2.63	443	313	1461	769	1576	1397	535	1286	4.67
56		306	1.029	.203	6993	600	3.19	443	315	1414	760	1454	1348	488	1168	4.49
57		303	1.033	.216	6294	770	2.14	436	313	1392	731	1707	1332	585	1444	4.45
58		308	1.029	.203	6294	756	2.17	440	317	1400	724	1681	1381	585	1410	4.41
59		308	1.026	.192	6294	598	2.50	437	316	1294	707	1430	1236	498	1192	4.10
60		298	1.030	.206	6294	513	2.79	438	305	1207	700	1340	1148	440	1103	3.96
61		315	1.022	.176	6294	503	3.19	437	322	1260	700	1310	1198	448	1069	3.92
62		306	1.029	.203	5944	660	2.14	446	315	1235	708	1580	1180	539	1356	3.92
63		307	1.023	.180	5944	602	2.31	441	314	1195	696	1464	1146	501	1243	3.81
64		307	1.026	.192	5944	544	2.45	438	315	1159	691	1379	1107	470	1154	3.68
65		306	1.026	.192	5944	490	2.70	441	314	1122	685	1300	1064	429	1078	3.57
66		308	1.023	.180	5944	460	2.91	448	315	1108	694	1275	1047	425	1044	3.52
67		308	1.023	.180	5944	453	3.19	443	315	1103	684	1240	1046	417	1020	3.50
68		310	1.035	2223	5455	572	2.14	441	321	1046	663	1495	1010	565	1300	3.26
69		313	1.026	.192	5455	558	2.23	441	321	1044	662	1449	1007	547	1254	3.25
70		310	1.026	.192	5455	517	2.34	441	318	1011	656	1370	968	504	1180	3.18
71		313	1.019	.184	5455	471	2.50	442	319	975	651	1300	934	486	1110	3.06
72		313	1.029	.203	5455	433	2.69	442	322	961	649	1240	920	435	1047	2.98
73		310	1.029	.203	5455	407	3.18	442	319	941	648	1195	900	409	1002	2.95

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EXHAUST-NOZZLE AREA AND ENGINE SPEED CONTROLLED SEPARATELY - ORIGINAL COMBUSTORS INSTALLED

Air flow $W_{a,1}$ (lb/sec)	Corrected engine speed, $N/\sqrt{\theta_1}$ (rpm)	Corrected air flow $\frac{W_{a,1}\sqrt{\theta_1}}{\delta_1}$ (lb/sec)	Compressor efficiency η_c (percent)	Burner combustion parameter $\frac{P_3^m T_3}{V_3}$	Combustion efficiency η_b (percent)	Burner pressure-loss coefficient $\frac{P_3-P_4}{q_b}$	Fuel-air ratio f/a	Combustion-chamber stagnation-temperature ratio T_4/T_3	Burner pressure loss $\frac{P_3-P_4}{P_3}$	Turbine pressure ratio P_4/P_6	Turbine efficiency η_t (percent)	Corrected turbine-inlet temperature T_4/θ_1 (°R)	Corrected turbine speed, $N/\sqrt{\theta_4}$ (rpm)	Corrected turbine gas flow $\frac{W_{g,4}\sqrt{\theta_1}}{\delta_4 \gamma/1.4}$ (lb/sec)	Run
59.66	8281	100.12	75.9	19,575	95.2	12.17	0.0186	2.364	0.044	2.547	82.8	2253	4111	40.18	1
60.64	8305	101.18	74.8	18,618	98.4	11.82	.0171	2.314	.046	2.568	83.6	2204	4183	40.93	2
61.03	8329	101.25	74.8	18,634	97.4	12.08	.0169	2.292	.047	2.613	82.5	2185	4191	40.75	3
60.90	8321	101.25	73.9	17,320	98.2	11.39	.0153	2.199	.047	2.697	83.5	2090	4275	40.76	4
61.03	8313	101.27	74.2	16,955	97.6	11.17	.0141	2.110	.047	2.787	84.0	1988	4371	40.58	5
61.26	8321	101.73	73.9	16,132	98.1	12.09	.0130	2.041	.053	2.863	84.8	1915	4452	40.83	6
61.11	8313	101.75	73.9	15,762	97.0	10.98	.0120	1.964	.049	3.034	82.1	1831	4541	40.48	7
58.63	7704	97.81	79.8	17,471	98.1	10.87	.0164	2.323	.042	2.411	85.5	2111	3939	40.76	8
58.75	7696	97.88	80.6	16,418	96.9	10.60	.0148	2.213	.042	2.485	83.1	1965	4052	40.53	9
58.71	7704	97.89	81.0	16,001	97.6	10.49	.0141	2.168	.043	2.536	84.2	1937	4101	40.25	10
58.59	7704	97.86	79.7	14,941	96.0	10.20	.0124	2.028	.045	2.655	84.3	1803	4238	40.21	11
58.63	7711	97.83	79.1	14,192	95.5	10.28	.0108	1.916	.047	2.776	84.3	1689	4373	40.17	12
58.63	7696	97.85	79.0	13,404	96.3	9.88	.0095	1.824	.048	2.924	84.4	1594	4485	40.14	13
52.86	6909	88.59	84.9	14,021	95.6	10.60	.0139	2.199	.042	2.320	82.2	1854	3755	40.12	14
53.66	6935	89.38	83.0	13,309	95.5	10.63	.0123	2.081	.046	2.412	82.7	1758	3860	40.23	15
53.62	6942	89.38	83.7	12,774	95.3	10.59	.0111	1.890	.047	2.485	83.8	1666	3964	39.89	16
53.00	6929	89.37	83.6	12,368	94.5	10.46	.0103	1.923	.048	2.559	83.2	1600	4029	39.86	17
53.98	6915	90.02	85.0	11,600	93.5	10.48	.0090	1.818	.050	2.652	82.5	1494	4154	39.64	18
53.64	6915	89.30	83.6	10,902	93.8	10.60	.0079	1.728	.053	2.758	82.8	1412	4264	39.66	19
46.20	6200	76.50	84.3	11,074	93.7	11.00	.0118	2.088	.046	2.189	83.3	1658	3547	39.82	20
46.59	6211	77.40	84.6	10,666	93.5	10.80	.0107	2.010	.047	2.254	81.6	1588	3627	39.88	21
46.13	6206	76.57	85.0	9,924	92.3	11.00	.0098	1.923	.049	2.295	82.2	1503	3717	39.51	22
46.08	6206	76.53	85.3	9,456	92.8	11.17	.0069	1.851	.051	2.351	83.6	1437	3796	39.35	23
46.56	6206	77.29	84.0	8,945	91.9	10.76	.0076	1.735	.054	2.452	84.1	1341	3918	39.52	24
46.46	6200	77.33	84.6	8,723	93.6	10.54	.0069	1.683	.055	2.479	85.6	1289	3989	39.53	25
37.03	5349	61.39	84.4	7,830	91.5	10.41	.0100	2.015	.046	1.928	78.4	1456	3253	39.93	26
36.64	5354	60.51	83.0	7,431	88.8	11.55	.0094	1.942	.051	1.979	80.9	1404	3312	39.25	27
37.11	5354	61.42	81.7	7,252	88.1	11.17	.0084	1.839	.051	2.013	80.9	1332	3393	39.07	28
37.13	5349	61.48	83.7	7,147	86.8	10.69	.0080	1.798	.051	2.035	77.0	1283	3448	39.25	29
37.13	5349	61.48	84.8	6,877	90.8	11.17	.0074	1.775	.054	2.054	81.2	1259	3481	39.21	30
38.02	5354	63.44	84.7	6,841	90.1	11.04	.0067	1.700	.055	2.156	81.3	1212	3546	39.21	31
23.97	4291	39.44	76.8	5,511	81.0	11.53	.0111	2.129	.042	1.531	76.1	1377	2677	36.87	32
34.91	4304	41.06	77.4	5,419	78.0	10.82	.0106	2.055	.042	1.537	54.9	1331	2729	37.53	33
25.82	4296	42.54	75.8	5,441	83.9	9.07	.0095	2.033	.040	1.532	80.0	1306	2747	39.70	34
24.93	4296	41.08	76.5	4,992	78.9	11.17	.0095	1.976	.046	1.554	76.6	1267	2787	37.87	35
25.87	4291	42.59	77.4	4,795	81.7	10.16	.0087	1.917	.046	1.562	75.6	1225	2829	38.90	36
24.77	4291	40.99	75.0	4,821	80.4	11.24	.0086	1.893	.047	1.566	81.5	1212	2843	37.58	37
25.18	4296	41.46	75.3	4,656	78.9	10.88	.0085	1.879	.047	1.570	80.1	1199	2861	37.96	38
16.66	8615	100.47	68.7	5,216	92.3	10.55	0.0193	2.400	0.040	2.253	95.7	2418	4124	41.07	39
16.28	8615	99.41	68.8	5,246	93.7	9.97	.0175	2.321	.039	2.250	93.6	2320	4211	40.65	40
16.03	8623	98.40	69.0	5,545	92.6	9.65	.0164	2.249	.039	2.419	94.1	2213	4300	40.48	41
15.50	8615	97.38	70.1	5,130	90.6	10.51	.0158	2.196	.041	2.552	80.9	2139	4366	39.78	42
15.79	8615	98.89	70.2	4,477	93.4	8.36	.0145	2.151	.035	2.771	83.9	2074	4429	40.55	43
16.10	8043	97.77	72.3	4,487	91.8	13.11	.0186	2.428	.047	2.473	82.7	2353	3900	40.82	44
15.38	8014	94.32	73.4	4,487	90.7	12.00	.0178	2.360	.043	2.532	82.9	2246	3971	39.50	45
15.78	8043	96.11	72.5	4,418	93.4	11.05	.0160	2.299	.043	2.552	82.9	2179	4040	40.74	46
15.80	8051	96.15	72.2	4,258	91.1	10.07	.0148	2.197	.041	2.667	83.2	2066	4149	40.78	47
16.09	8058	97.82	72.3	4,586	93.8	9.56	.0144	2.189	.039	2.687	83.1	2070	4145	40.50	48
15.39	8058	95.67	73.5	3,915	88.9	12.45	.0143	2.137	.050	2.728	81.1	2000	4211	39.86	49
15.64	8043	97.40	73.6	4,056	89.1	11.36	.0141	2.119	.048	2.717	81.3	1979	4225	40.35	50
15.96	8021	98.41	72.5	3,795	92.0	10.30	.0119	1.999	.047	2.869	83.0	1848	4350	41.17	51
15.03	7587	92.47	76.1	4,544	89.8	12.48	.0198	2.519	.041	2.301	83.4	2385	3671	39.48	52
15.01	7573	93.10	76.5	4,425	91.2	11.92	.0180	2.429	.045	2.354	83.5	2251	3750	40.05	53
15.40	7587	95.04	75.6	3,979	89.0	9.91	.0135	2.111	.044	2.597	85.7	1905	4059	41.09	54
14.92	7573	93.13	75.2	3,724	87.4	10.19	.0130	2.049	.044	2.611	84.5	1847	4109	40.02	55
15.31	7573	94.96	75.0	3,582	86.2	9.73	.0111	1.913	.047	2.762	84.6	1704	4264	40.74	56
13.32	6867	82.53	78.6	3,610	84.5	11.97	.0164	2.335	.043	2.277	82.9	2031	3564	39.17	57
13.79	6835	84.76	82.1	3,629	85.1	11.08	.0158	2.294	.042	2.292	80.4	1959	3611	39.70	58
13.79	6860	84.71	80.4	3,116	81.5	10.42	.0123	2.023	.045	2.482	79.1	1699	3871	39.73	59
13.19	6854	84.03	80.6	2,811	79.4	10.87	.0110	1.914	.049	2.609	79.1	1587	3991	39.42	60
14.60	6860	88.02	79.3	2,934	85.4	9.65	.0097	1.871	.049	2.674	80.2	1556	4032	41.33	61
12.65	6414	78.13	81.5	3,166	82.3	11.41	.0149	2.232	.045	2.189	78.7	1839	3490	39.92	62
12.58	6449	78.14	80.8	2,989	78.8	10.00	.0135	2.103	.041	2.287	76.5	1723	3618	39.59	63
12.68	6473	78.21	78.1	2,760	77.7	10.20	.0121	1.996	.045	2.355	81.5	1634	3717	39.99	64
12.95	6449	80.43	79.4	2,585	76.6	10.55	.0107	1.898	.052	2.480	80.0	1529	3823	41.19	65
12.53	6396	78.22	78.9	2,536	76.1	11.48	.0104	1.857	.055	2.484	85.3	1477	3857	39.49	66
12.95	6437	80.38	79.3	2,576	76.5	10.14	.0099	1.813	.052	2.508	81.5	1453	3908	40.85	67
11.31	5919	68.72	79.9	3,015	80.7	8.19	.0143	2.255	.034	1.788	94.4	1760	3286	41.09	68
11.77	5919	71.51	80.0	2,882	81.0	7.70	.0134	2.189	.035	1.841	92.3	1705	3334	42.17	69
11.41	5919	69.97	80.4	2,495	78.5	9.44	.0128	2.088	.043	1.921	88.7	1612	3424	41.15	70
11.38	5913	69.63	79.6	2,322	76.3	8.77	.0116	1.997	.042	2.004	87.4	1526	3508	41.48	71
11.82	5913	71.65	78.4	2,320	77.0	8.06	.0103	1.911	.043	2.115	86.0	1456	3586	42.55	72
11.84	5913	72.44	77.8	2,234	76.4	7.79	.0097	1.844	.044	2.200	85.0	1403	3649	42.62	73

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TABLE III - COMBUSTOR PERFORMANCE OF PROTOTYPE J47D (RX1-1) TURBOJET ENGINE ON ELECTRONIC CONTROL SCHEDULE - COMBUSTORS MODIFIED FOR BETTER ALTITUDE PERFORMANCE

Run	Altitude (ft)	Tunnel static pressure, p_0 (lb/sq ft abs.)	Ram pressure ratio P_1/p_0	Flight Mach number, M_0	Engine speed N (rpm)	Fuel flow W_f (lb/hr)	Exhaust-nozzle outlet area (sq ft)	Compressor-inlet stagnation temperature, T_1 (°R)	Burner-inlet stagnation pressure P_3 (lb/sq ft abs.)	Burner-inlet stagnation temperature T_3 (°R)	Burner-outlet stagnation temperature T_4 (°R)	Burner-outlet stagnation pressure P_4 (lb/sq ft abs.)	Compressor-inlet air flow, $W_{a,1}$ (lb/sec)	Corrected engine speed, $N/\sqrt{\theta_1}$ (lb/sec)	Burner-combustion parameter $\frac{P_3 T_3}{V_3}$	Combustion efficiency η_b (percent)	Burner pressure loss $\frac{P_3-P_4}{P_3}$	Burner pressure-loss coefficient $\frac{P_3-P_4}{q_b}$	Fuel-air ratio f/a	Burner temperature ratio, T_4/T_3
1	6000	1697	1.019	0.160	7955	5305	2.28	503	9295	903	2120	8800	82.83	8082	26,868	98.5	0.053	14.0	0.0183	2.348
2		1687	1.023	.180	7955	4680	2.43	502	9082	895	2005	8443	82.53	8090	22,111	101.3	.068	17.5	.0161	2.240
3		1683	1.024	.185	7950	4175	2.55	501	8621	884	1885	8271	83.04	8093	27,613	99.3	.041	9.2	.0143	2.110
4		1685	1.026	.190	7692	3820	2.55	498	8424	862	1787	8017	82.99	7854	23,432	100.0	.048	10.7	.0131	2.073
5		1690	1.025	.185	7386	3350	2.58	498	8027	829	1650	7609	81.50	7556	20,932	99.1	.052	11.3	.0117	1.990
6		1689	1.025	.185	6993	2880	2.63	495	7478	808	1569	7046	78.08	7181	17,766	101.0	.058	12.3	.0105	1.942
7		1690	1.028	.195	6818	2520	2.77	498	7144	789	1465	6721	76.13	6975	18,771	98.9	.059	12.3	.0094	1.857
8		1686	1.025	.185	6643	2220	2.815	496	6730	774	1395	6321	72.99	6796	15,276	98.2	.061	12.4	.0086	1.802
9		1686	1.026	.180	6294	1910	2.93	496	6175	749	1320	5741	68.42	6439	13,627	99.3	.070	14.3	.0079	1.762
10		1683	1.028	.190	6136	1768	2.945	497	5868	737	1290	5494	65.75	6271	12,697	98.6	.064	12.7	.0076	1.750
11		1689	1.027	.195	5944	1622	2.945	497	5538	722	1270	5184	62.76	6075	12,139	100.7	.064	12.8	.0073	1.759
12		1683	1.027	.195	5455	1340	2.945	497	4726	687	1210	4419	55.33	5575	10,226	101.5	.065	12.8	.0069	1.761
13	35,000	494	1.024	0.185	7955	1739	2.42	449	2905	854	2077	2771	25.81	8552	7,473	93.2	0.046	13.2	0.0194	2.432
14		493	1.020	.170	7692	1310	2.55	450	2640	817	1808	2495	24.83	8261	6,469	94.7	.055	14.1	.0160	2.213
15		491	1.024	.185	7500	1220	2.56	457	2552	798	1726	2414	24.63	7995	6,262	93.2	.054	13.9	.0141	2.163
16		493	1.020	.170	7386	1172	2.57	449	2520	793	1697	2384	24.58	7940	5,860	94.9	.054	13.5	.0136	2.140
17		493	1.020	.170	6993	970	2.63	448	2343	760	1538	2214	24.14	7524	5,467	95.4	.055	12.8	.0114	2.024
18		493	1.020	.170	6643	805	2.72	448	2176	733	1440	2050	23.20	7148	4,921	98.9	.057	12.8	.0098	1.965
19		494	1.024	.185	5944	590	2.91	449	1782	679	1240	1670	20.27	6390	3,881	91.6	.063	13.4	.0082	1.826
20	45,000	307	1.026	0.185	7955	1121	2.48	437	1816	855	2110	1732	15.97	8671	4,552	94.1	0.046	12.9	0.0188	2.468
21		308	1.029	.200	7955	1082	2.50	442	1805	863	2083	1725	15.99	8623	4,668	93.7	.045	12.6	.0193	2.414
22		308	1.026	.185	7955	1064	2.55	438	1790	853	2060	1710	16.03	8679	4,602	95.5	.045	12.1	.0187	2.415
23		307	1.029	.200	7692	902	2.55	436	1702	808	1875	1615	15.75	8392	4,319	95.4	.051	13.8	.0162	2.321
24		305	1.030	.205	7500	824	2.55	447	1611	800	1766	1527	15.45	8078	4,012	91.3	.052	13.4	.0152	2.208
25		303	1.030	.205	7500	778	2.63	442	1594	798	1810	1510	15.56	8130	3,965	101.9	.053	12.8	.0142	2.268
26		308	1.023	.180	7386	784	2.57	435	1493	787	1748	1512	15.71	8066	4,108	97.4	.051	12.4	.0141	2.219
27		303	1.026	.185	6993	670	2.63	437	1458	754	1604	1382	15.02	7622	3,574	94.5	.052	11.8	.0126	2.127
28		304	1.023	.180	6643	587	2.75	436	1361	730	1490	1284	14.30	7248	3,194	91.3	.057	12.9	.0116	2.041
29		306	1.036	.220	6643	558	2.94	438	1359	726	1421	1279	15.06	7234	3,139	91.4	.059	12.0	.0104	1.957
30		306	1.029	.200	5944	449	2.94	440	1123	677	1310	1078	13.33	6455	2,423	90.0	.062	11.8	.0095	1.935
31		306	1.028	.185	5944	433	2.91	437	1128	678	1305	1085	12.64	6479	2,551	88.0	.055	12.0	.0097	1.928

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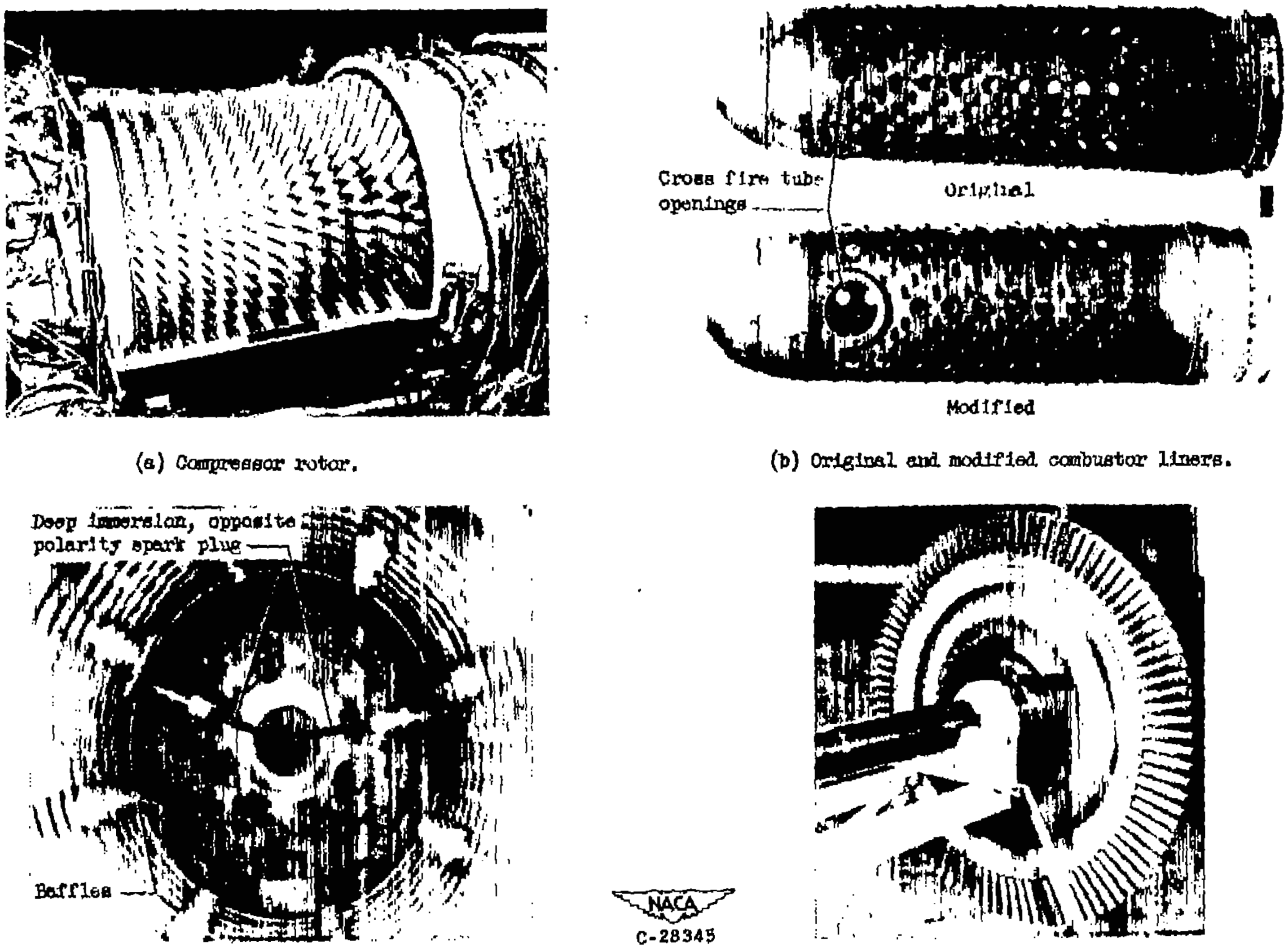


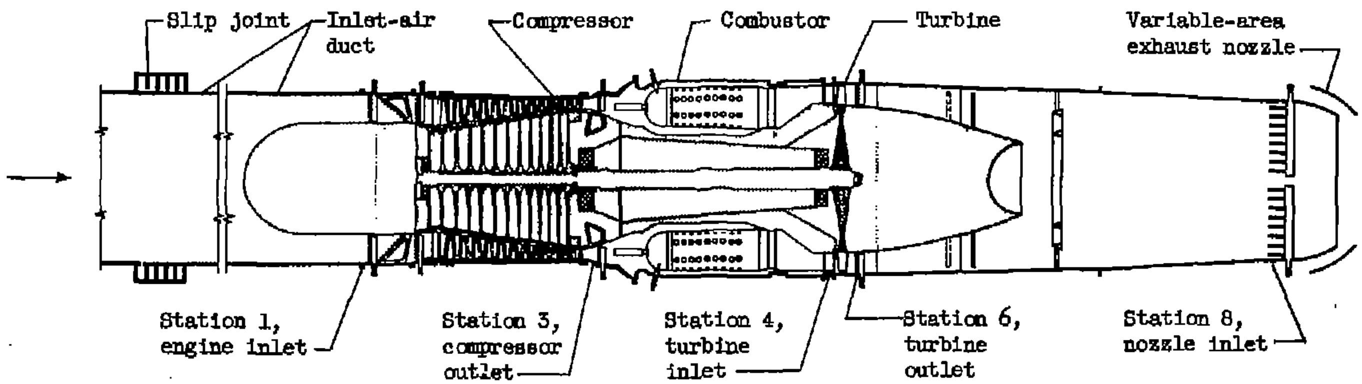
(a) Compressor rotor.

(b) Original and modified combustor liners.

(c) Interior of modified combustor liner.

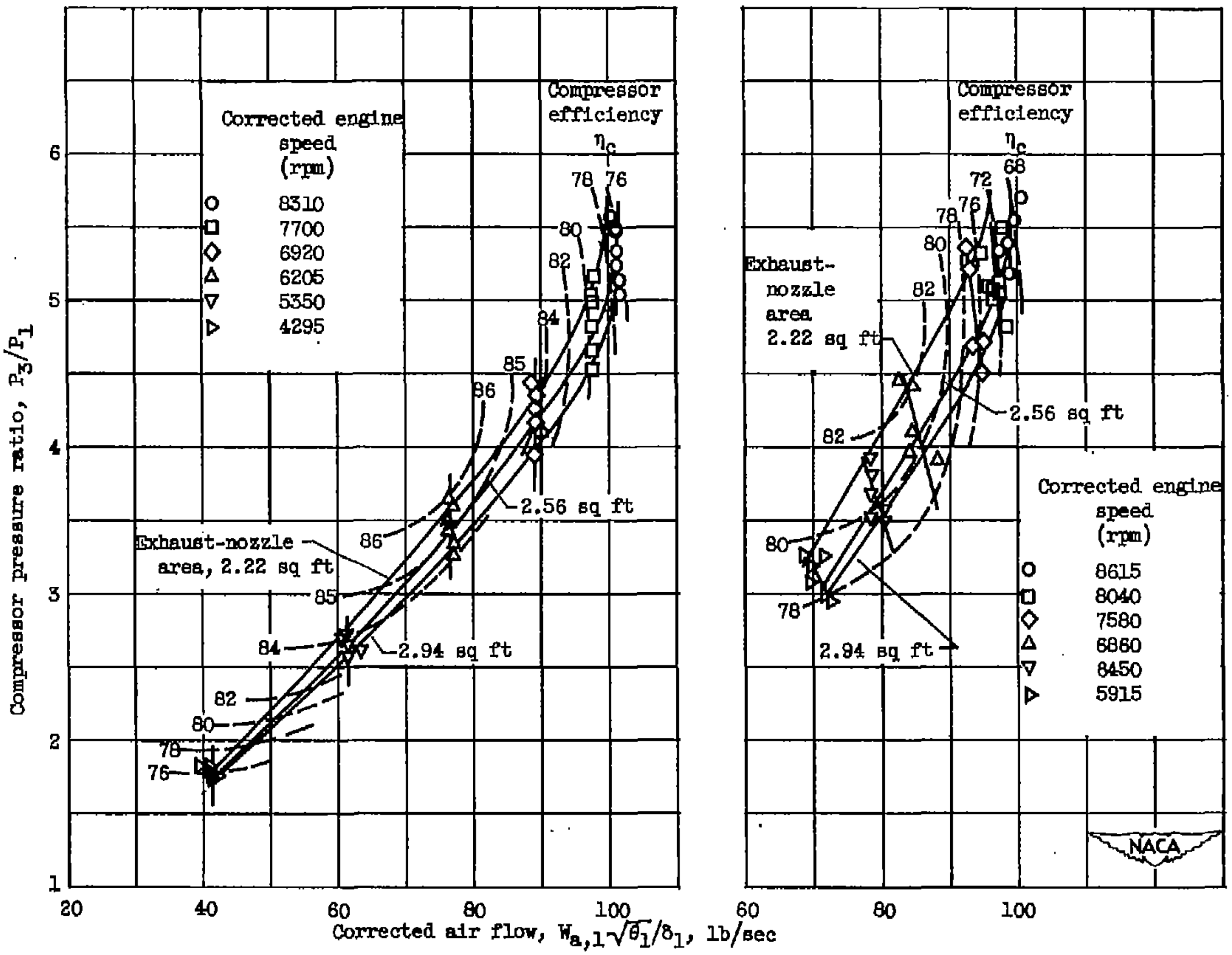
(d) Turbine rotor.

Figure 1. - Components of prototype J47D (RX1-1) turbojet engine.



Station	Total-pressure tubes	Static-pressure tubes	Wall static-pressure orifices	Thermo-couples
1	32	8	5	4
3	20	0	4	6
4	5	0	0	0
6	30	0	4	24
8	0	0	0	25

Figure 2. - Cross section of turbojet-engine installation showing sections at which component instrumentation was installed.



(a) Reynolds number index, 0.64; altitude, 15,000 feet.

(b) Reynolds number index, 0.18; altitude, 45,000 feet.

Figure 3. - Compressor performance maps at flight Mach number of 0.19.

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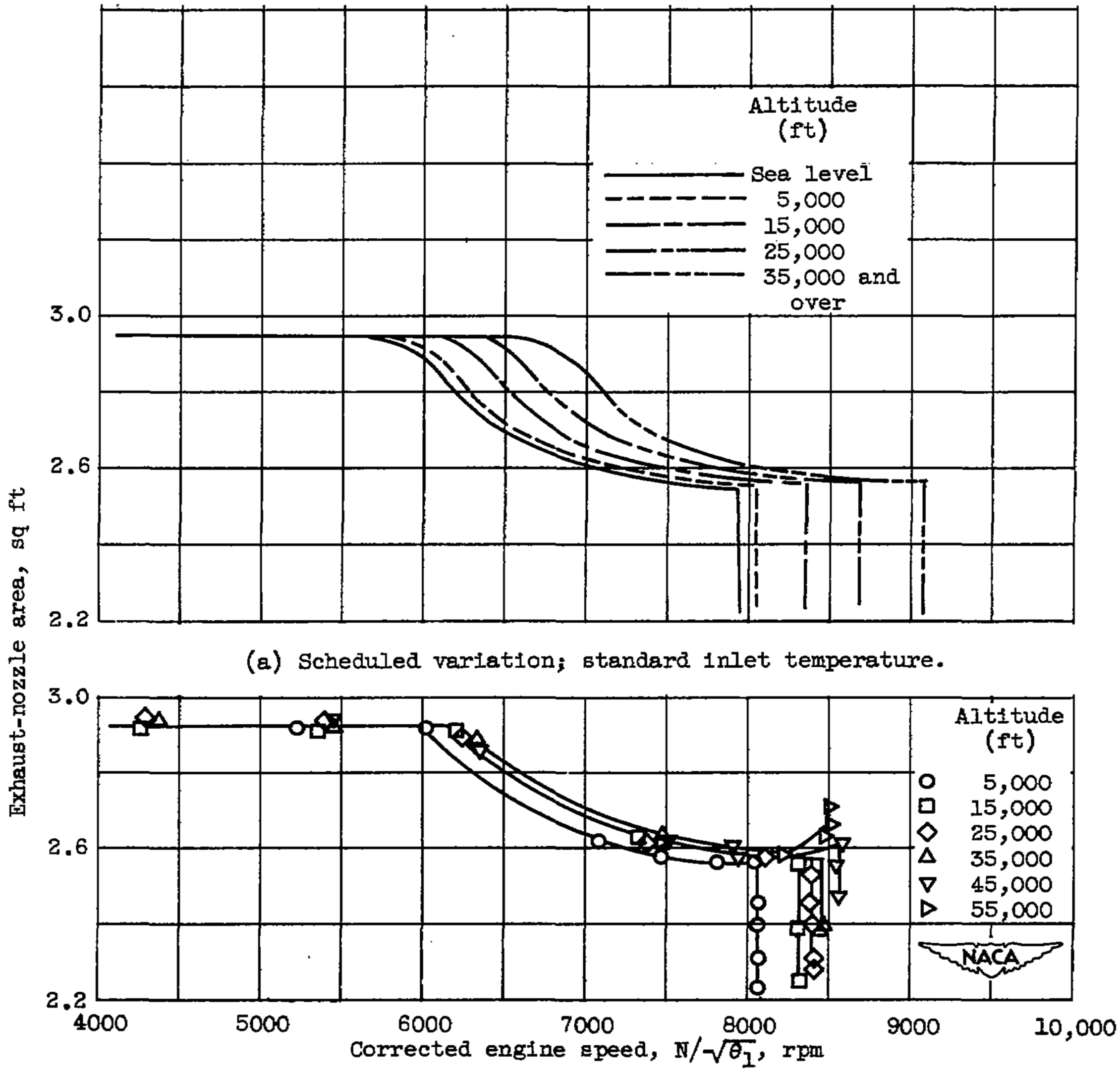

(a) Scheduled variation; standard inlet temperature.

(b) Experimental variation at a flight Mach number of 0.19.

Figure 4. - Variation of exhaust-nozzle area with altitude and corrected engine speed on electronic control schedule.

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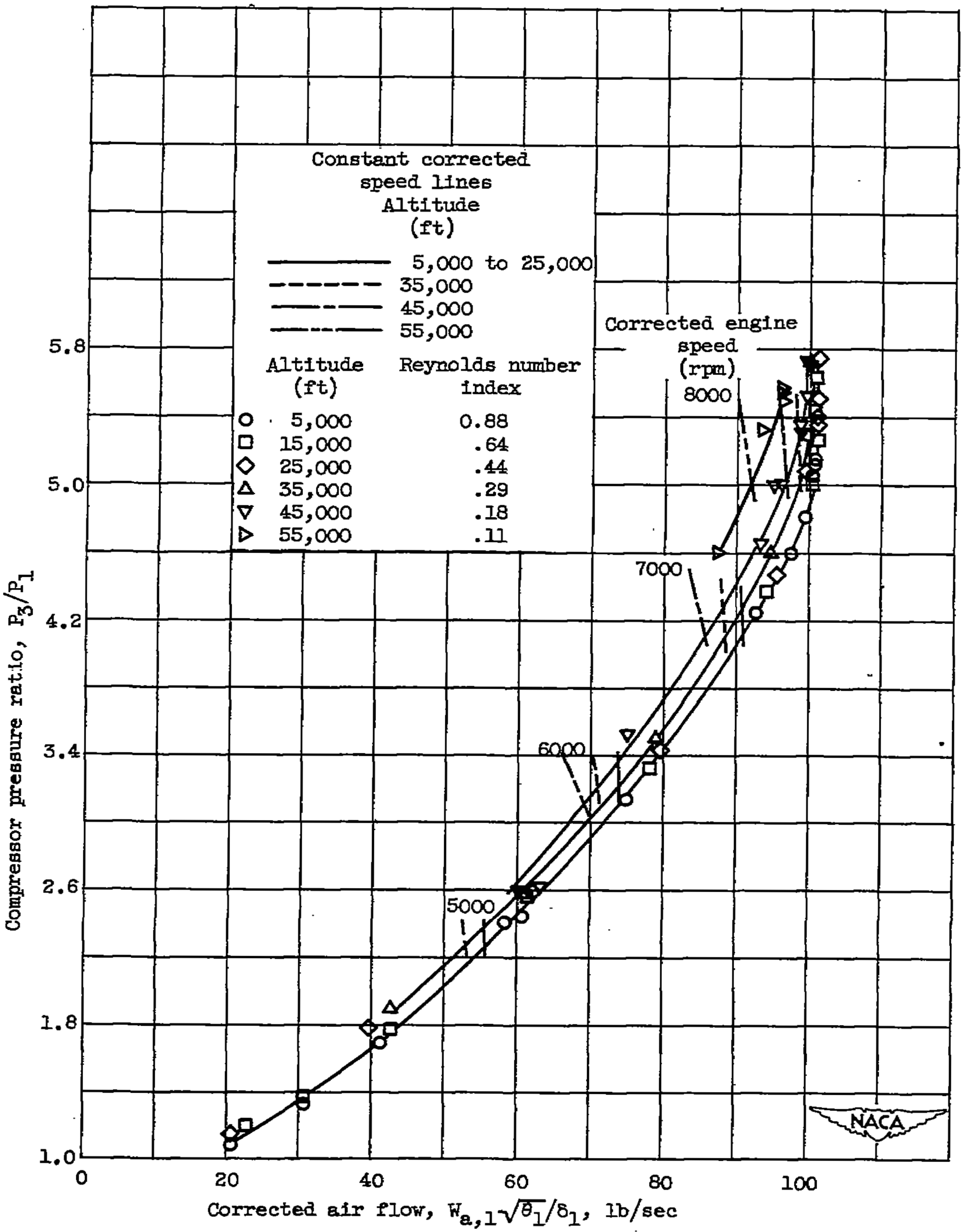
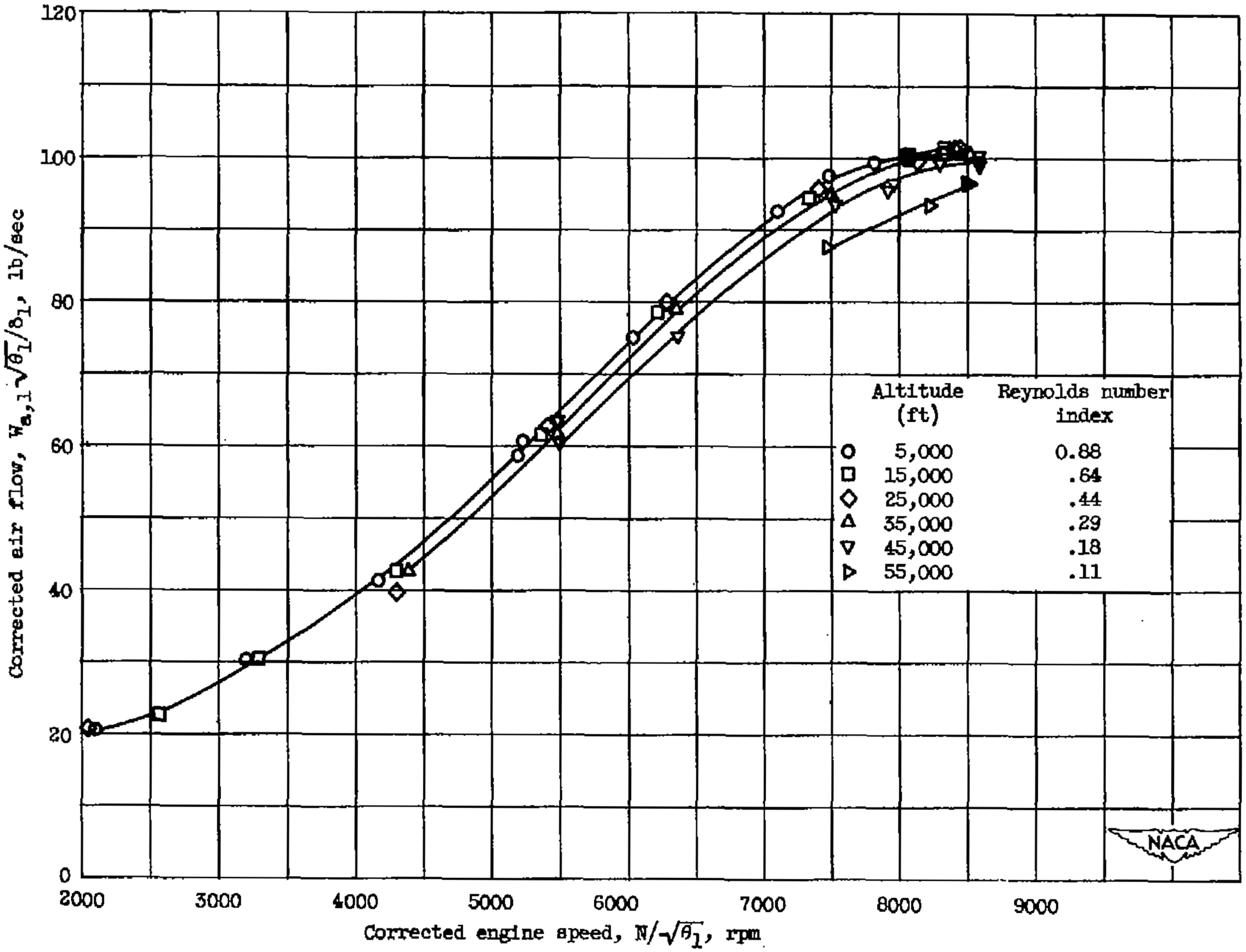


(a) Relation between corrected air flow and pressure ratio.

Figure 5. - Effect of altitude on compressor operating lines; flight Mach number, 0.19; engine on electronic control schedule.



(b) Relation between corrected air flow and corrected engine speed.

Figure 5. - Concluded. Effect of altitude on compressor operating lines; flight Mach number 0.19; engine on electronic control schedule.

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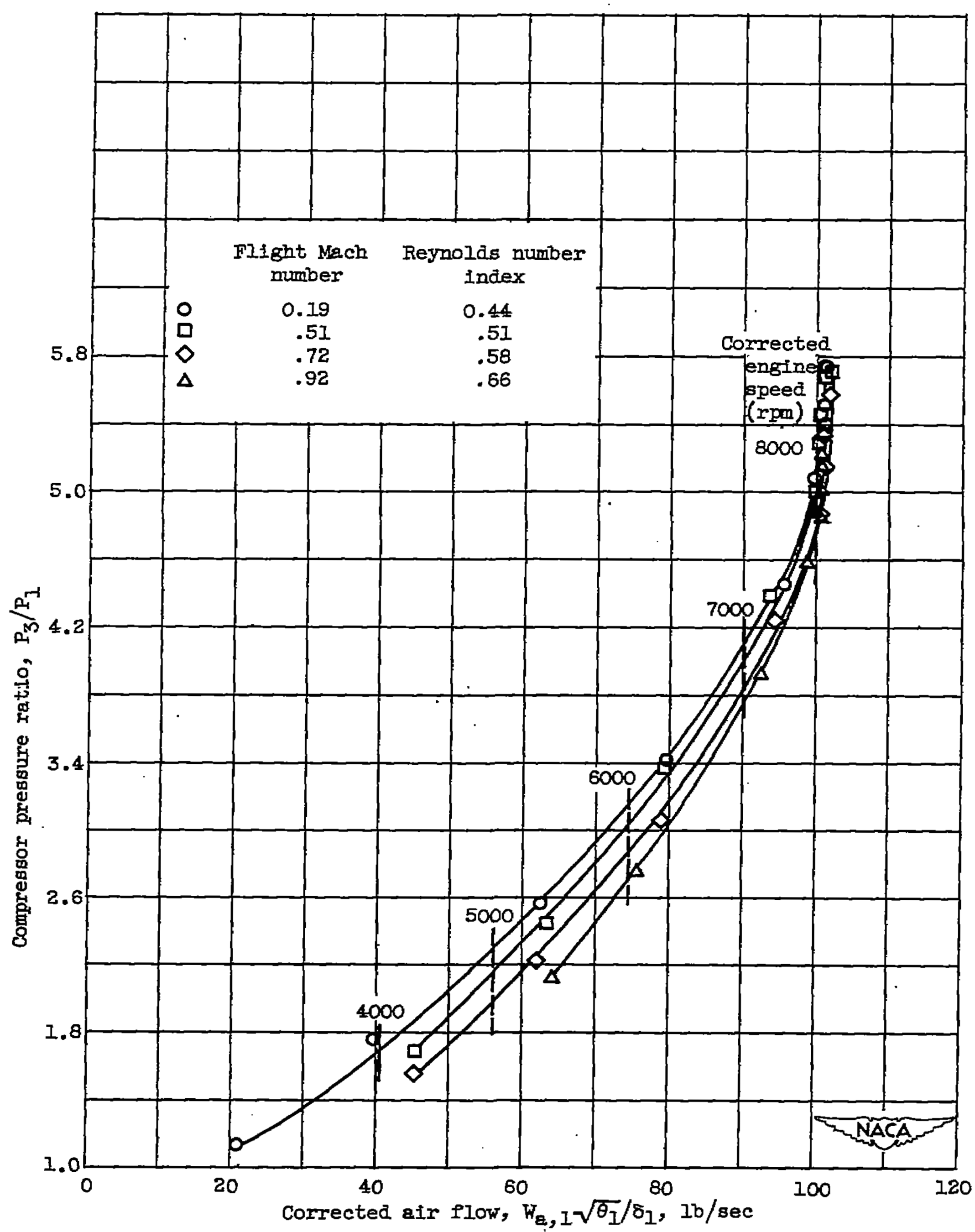
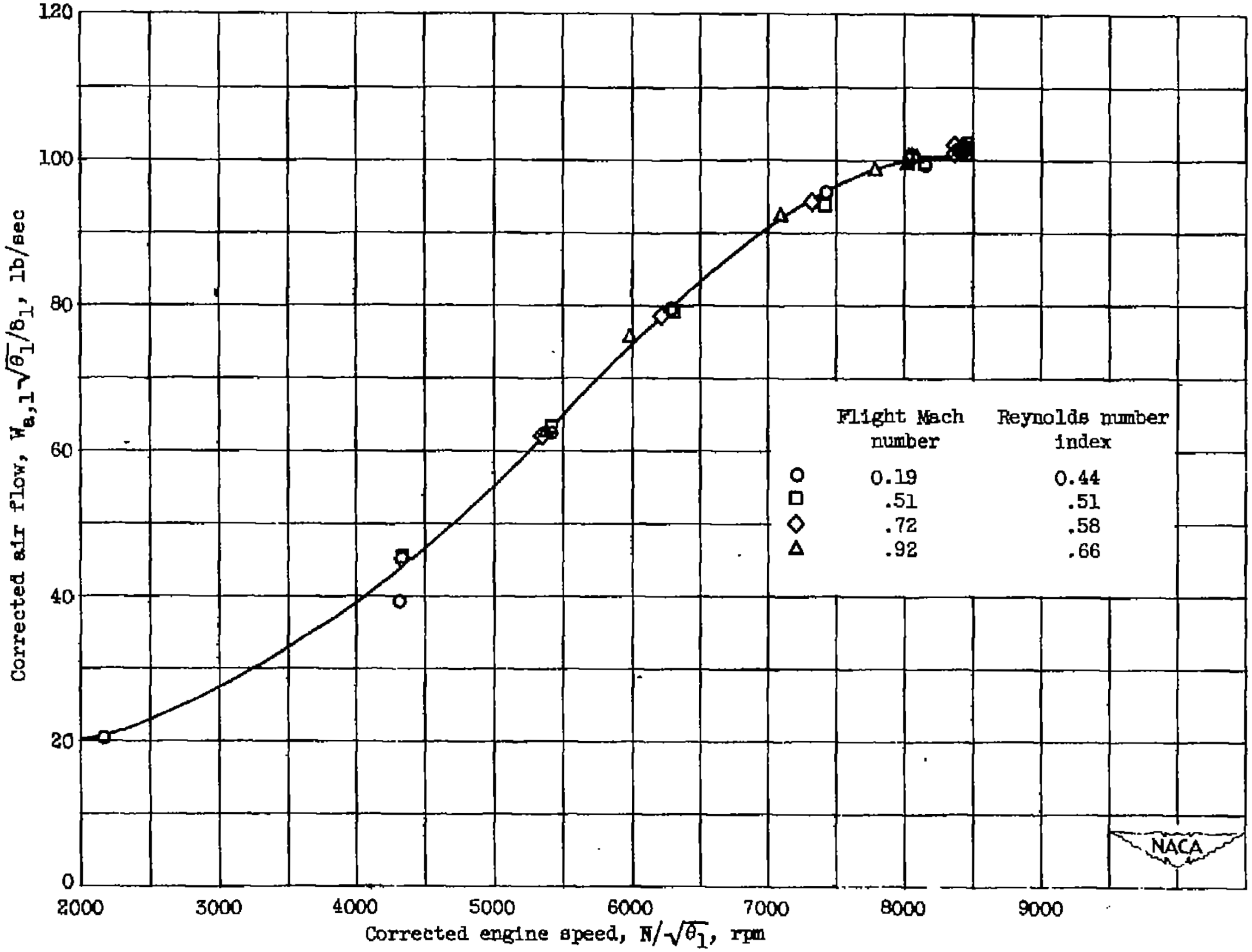


(a) Relation between corrected air flow and pressure ratio.

Figure 6. - Effect of flight Mach number on compressor operating lines; altitude 25,000 feet; engine on electronic control schedule.



(b) Relation between corrected air flow and corrected engine speed.

Figure 6. - Concluded. Effect of flight Mach number on compressor operating lines; altitude 25,000 feet; engine on electronic control schedule.

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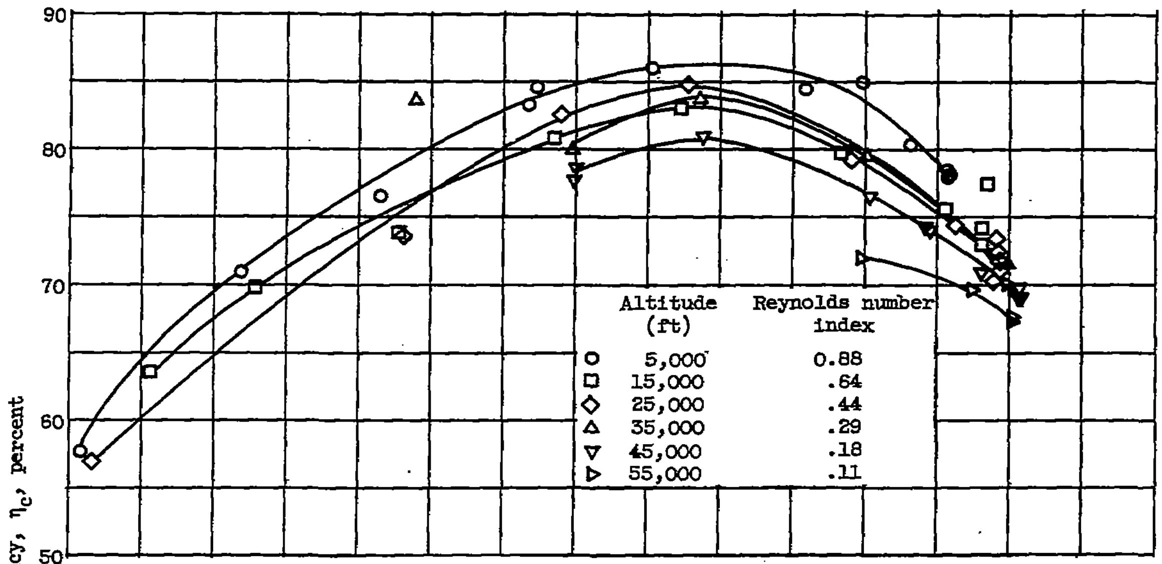
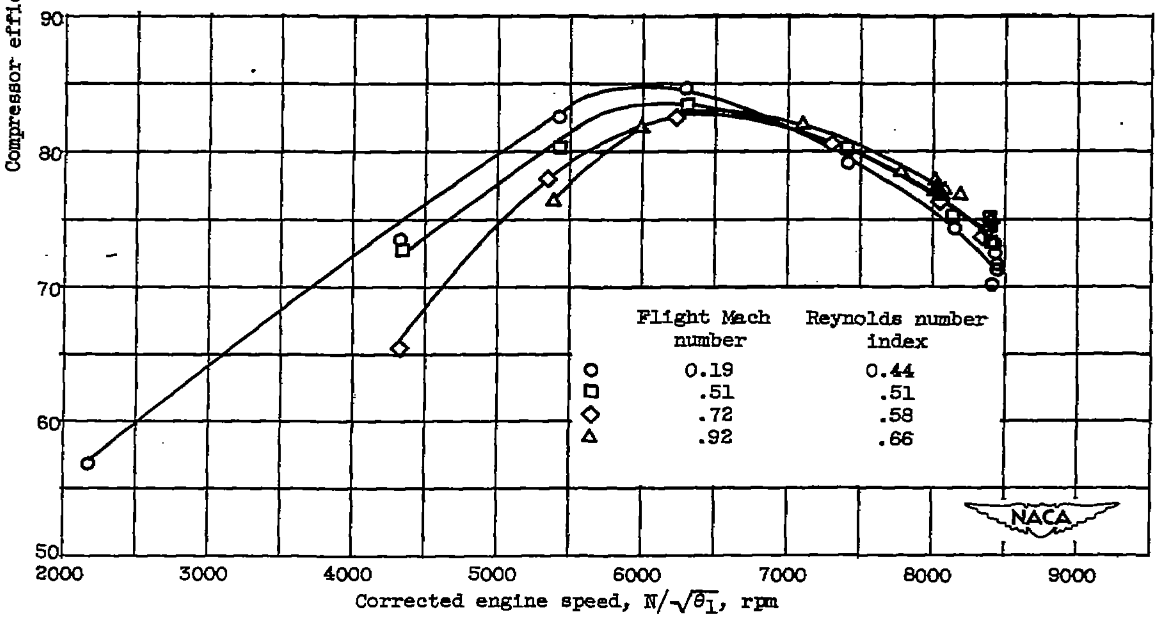


(a) Effect of altitude; flight Mach number, 0.19.



(b) Effect of flight Mach number; altitude 25,000 feet.

Figure 7. - Effect of corrected engine speed and flight condition on compressor efficiency; engine on electronic control schedule.

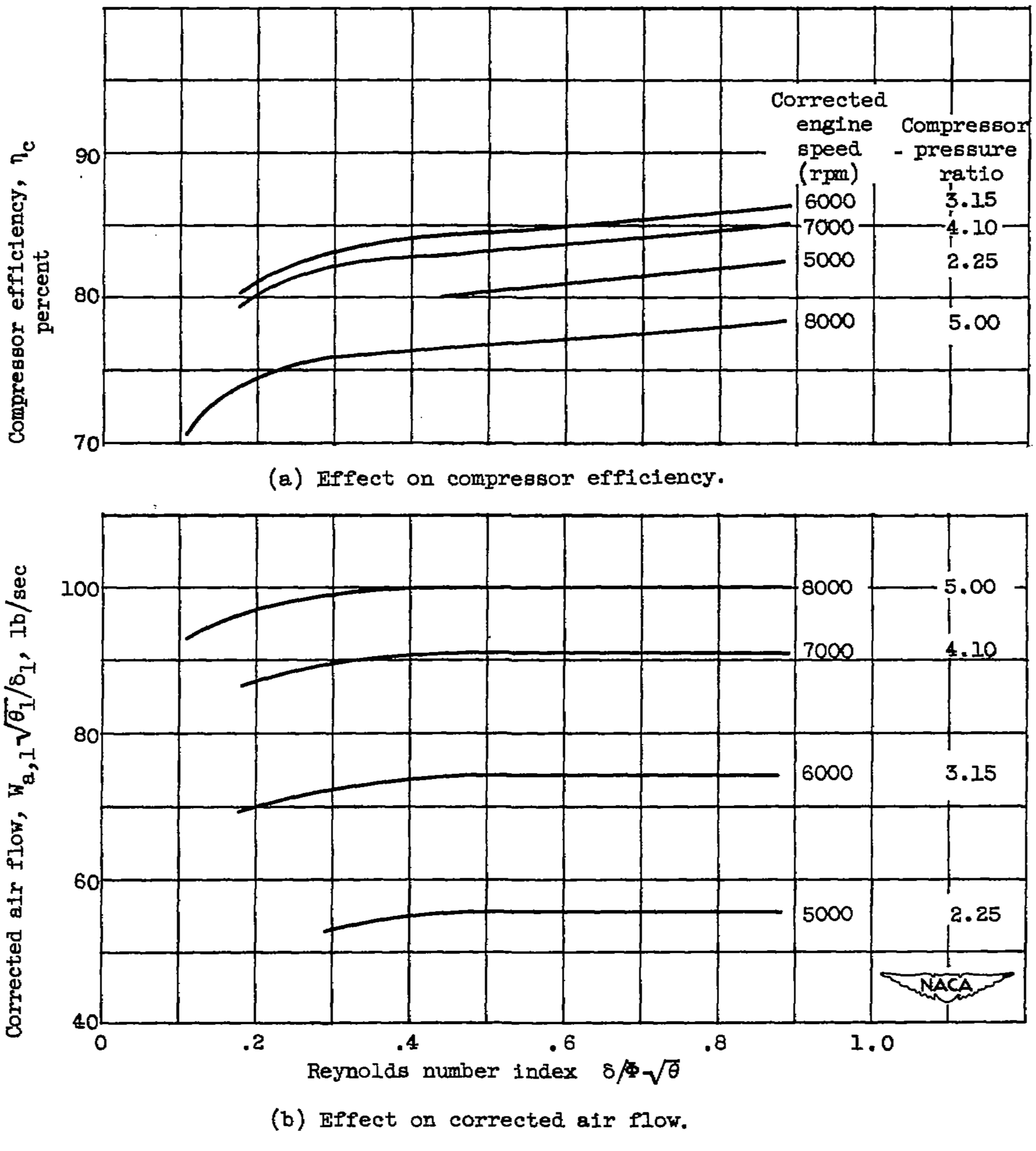


Figure 8. - Effect of Reynolds number index on compressor performance.

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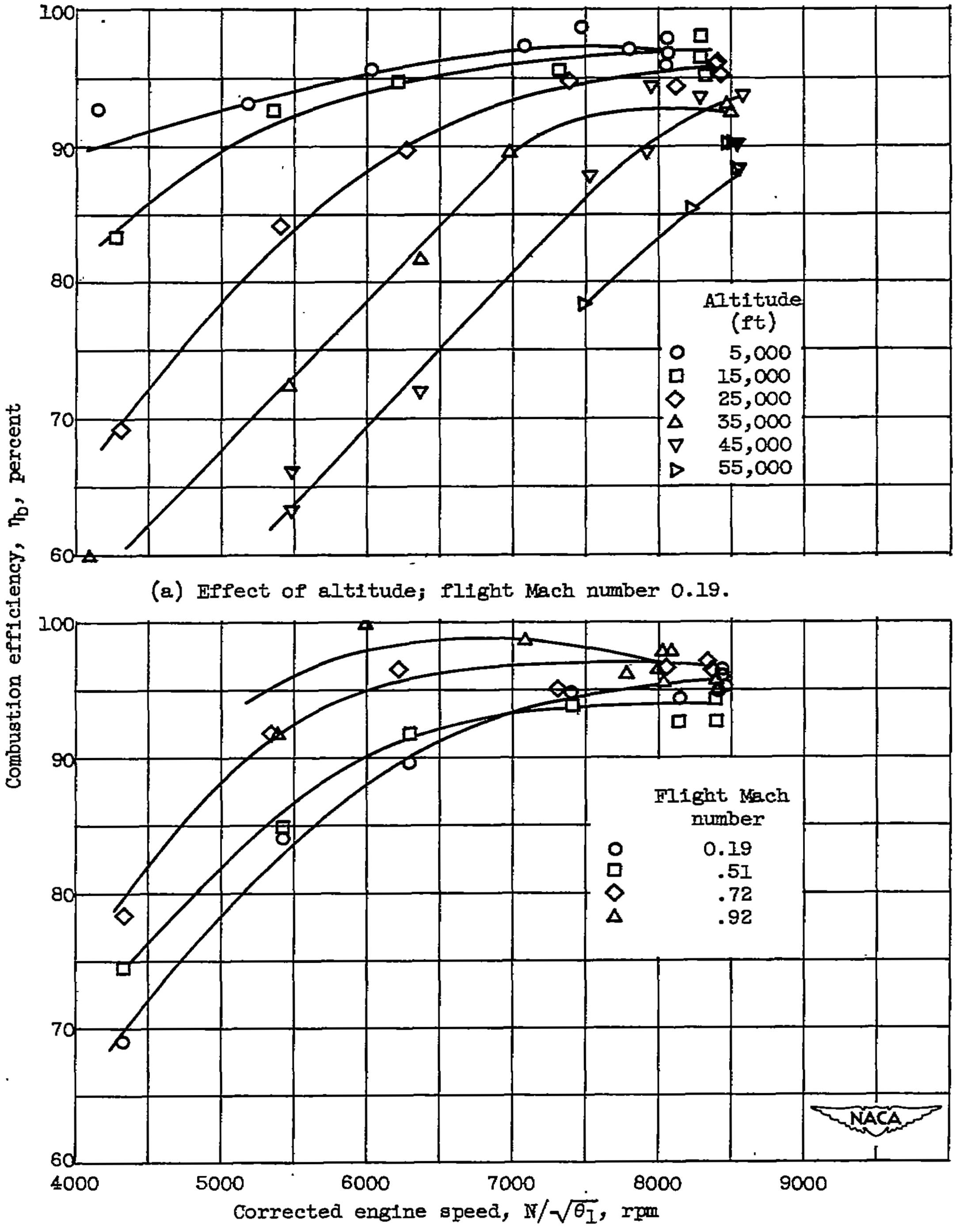
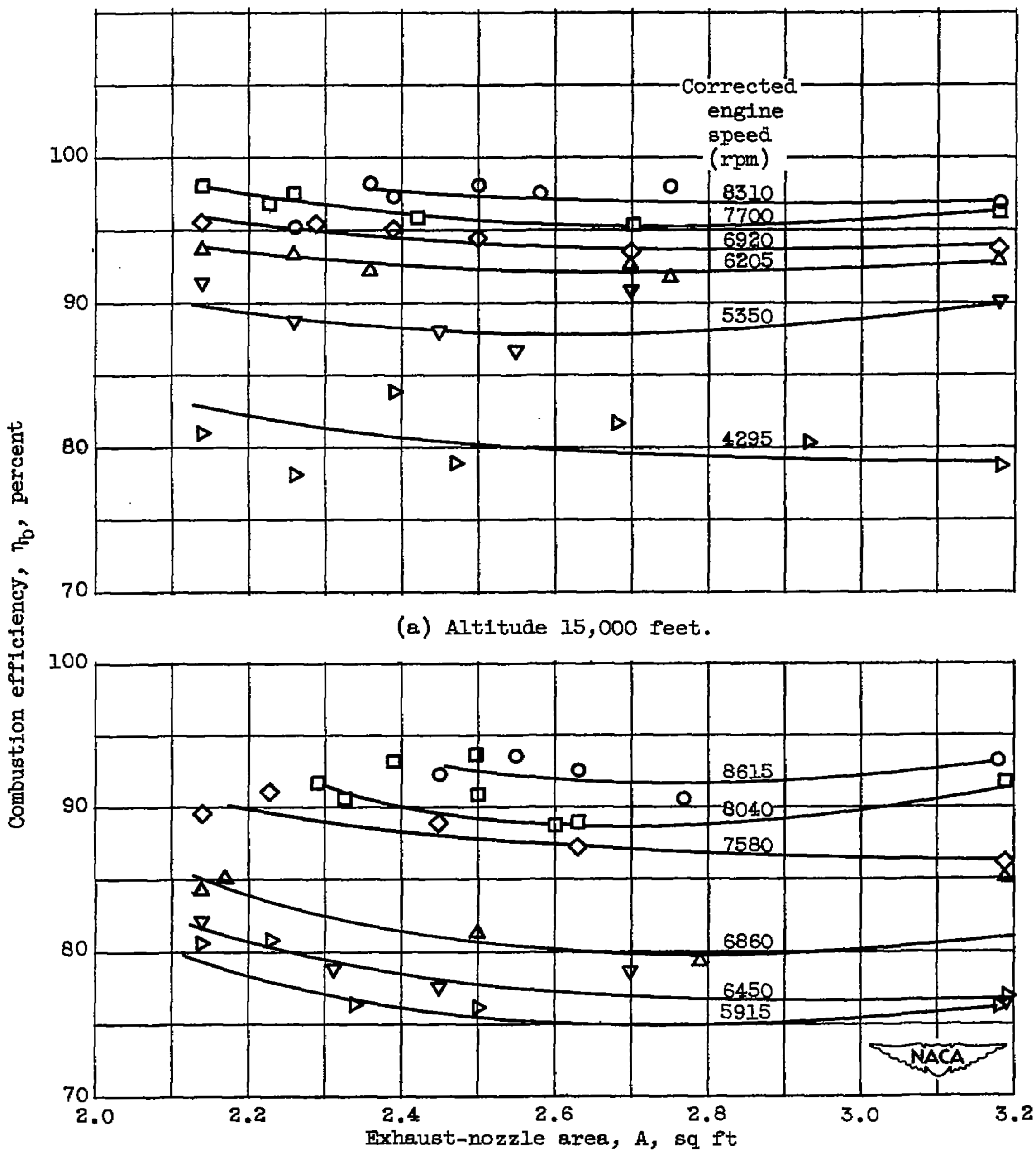


(a) Effect of altitude; flight Mach number 0.19.

(b) Effect of Mach number altitude 25,000 feet.

Figure 9. - Effect of flight conditions on combustion efficiency; engine on electronic control schedule.



(a) Altitude 15,000 feet.

(b) Altitude 45,000 feet.

Figure 10. - Effect of exhaust-nozzle area on combustion efficiency; flight Mach number, 0.19.

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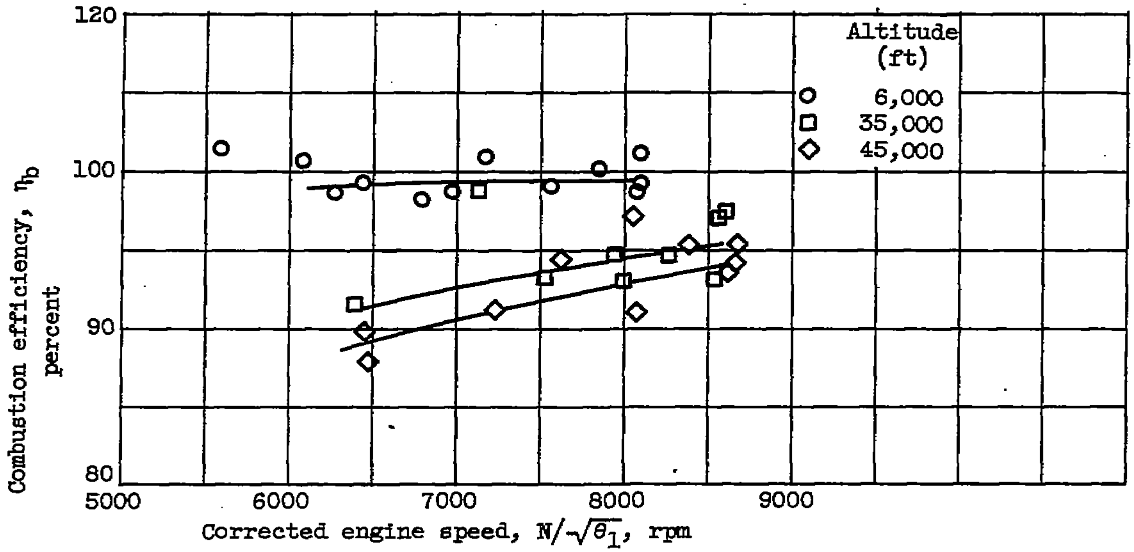

Figure 11. - Effect of altitude on combustion efficiency: modified combustors; flight Mach number, 0.19; engine on electronic control schedule.

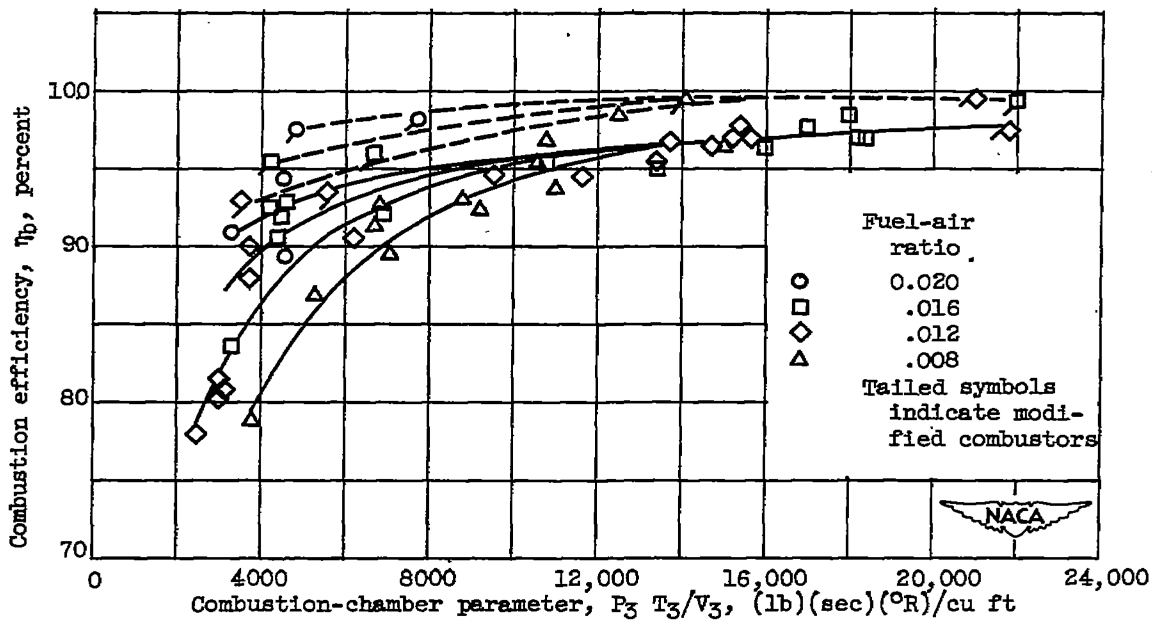

Figure 12. - Comparison of original and modified combustion-chamber performance.

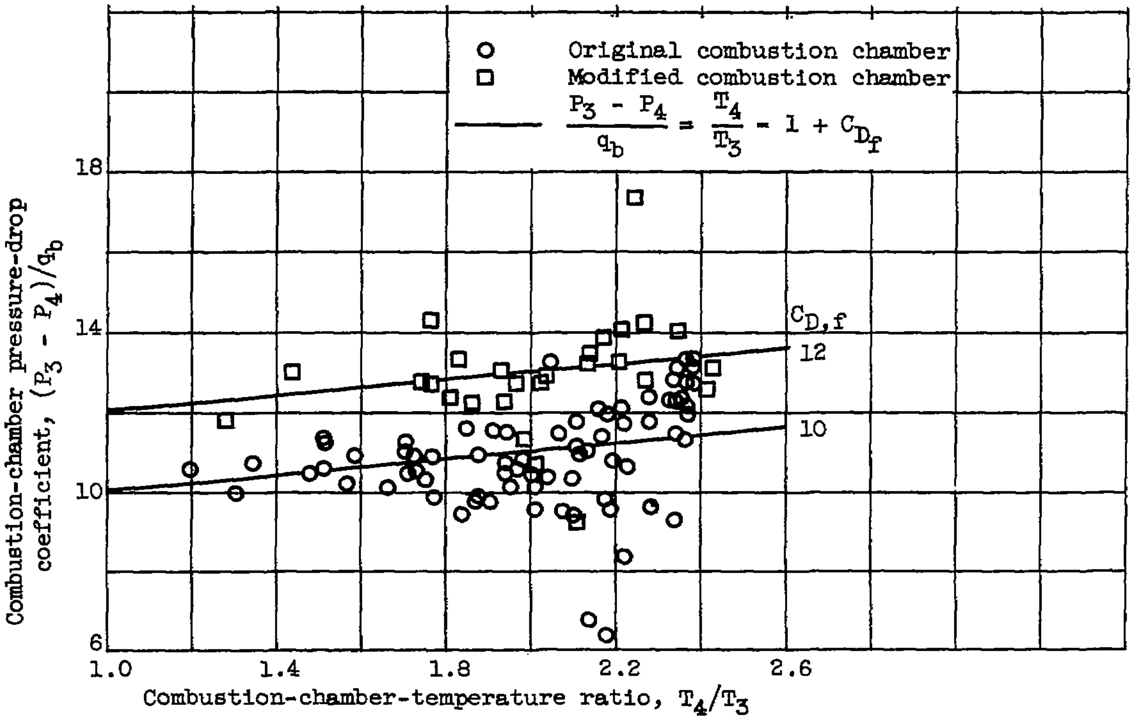

Figure 13. - Effect of combustion-temperature ratio on pressure-drop coefficient.

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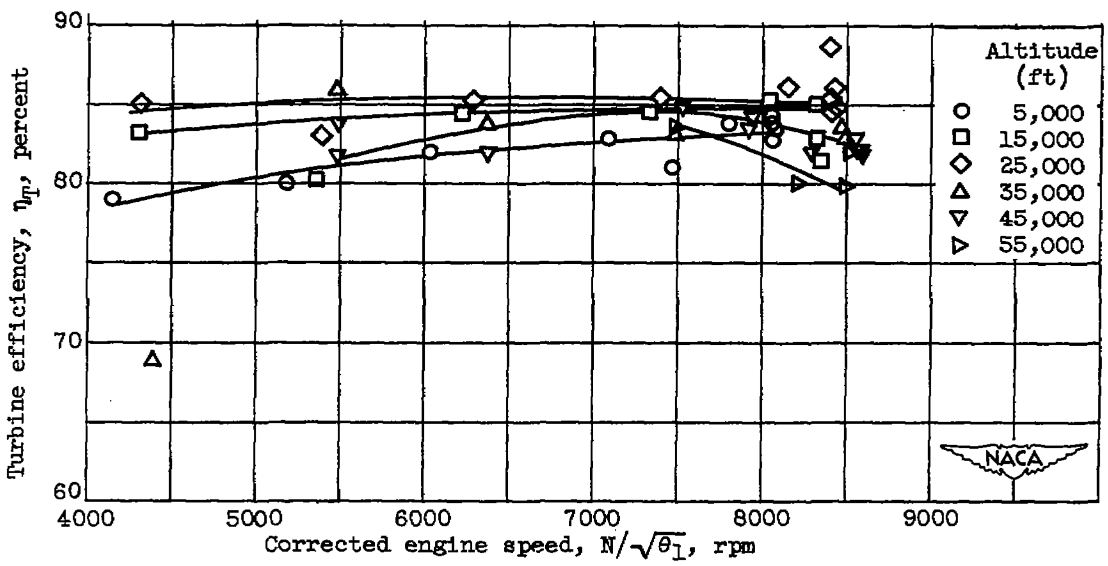

(a) Turbine efficiency.

Figure 14. - Variation of turbine-performance parameters with altitude and corrected engine speed; flight Mach number, 0.19; engine on electronic control schedule.

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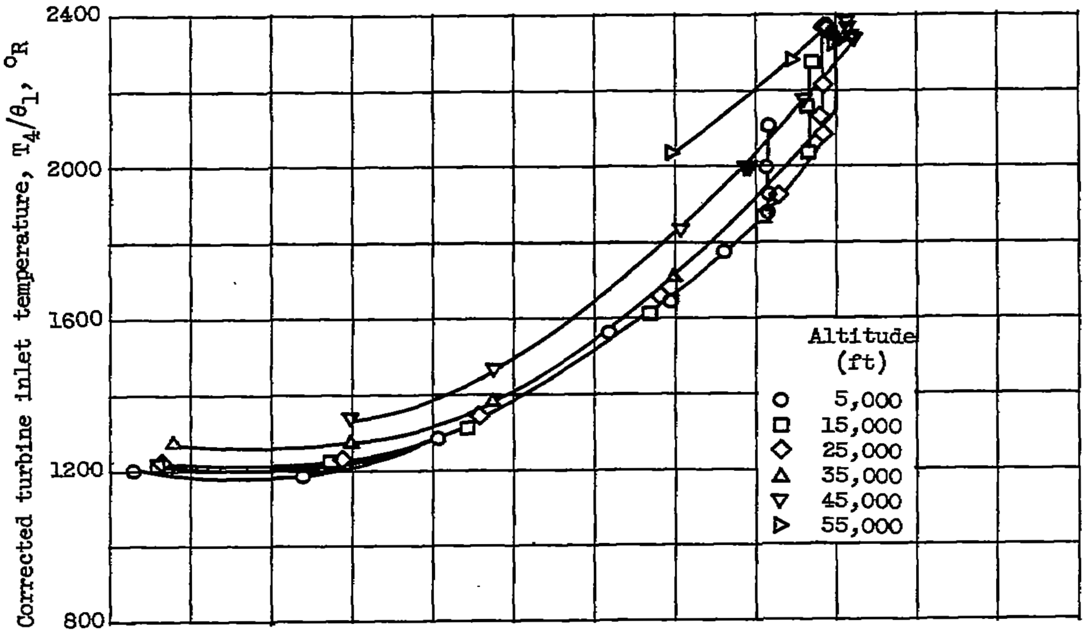
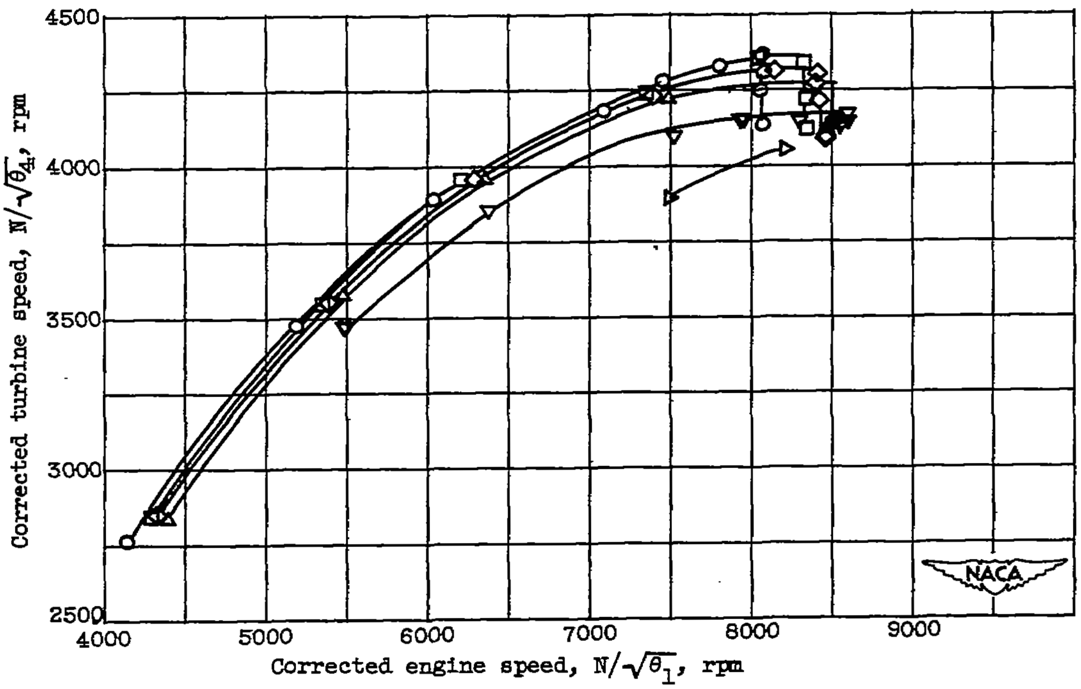


(b) Corrected turbine-inlet temperature.



(c) Corrected turbine speed.

Figure 14. - Continued. Variation of turbine-performance parameters with altitude and corrected engine speed; flight Mach number, 0.19; engine on electronic control schedule.

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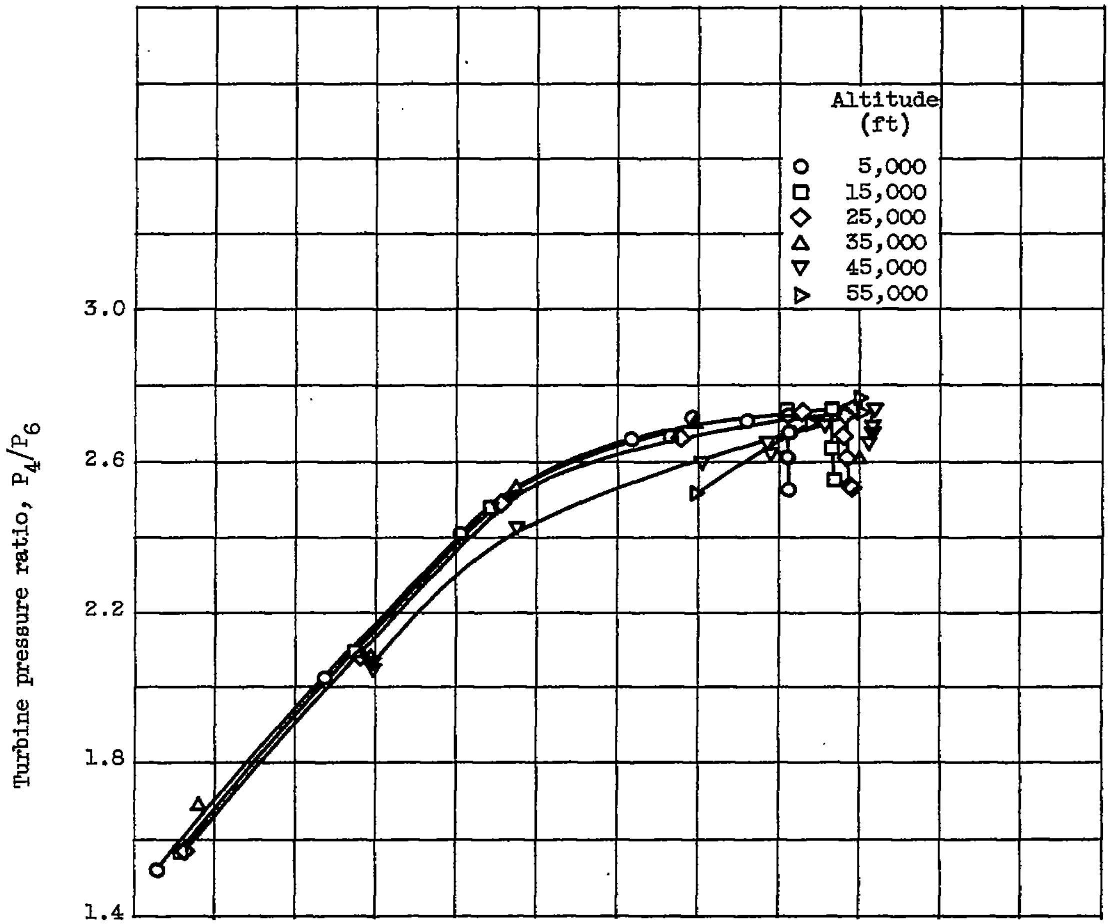
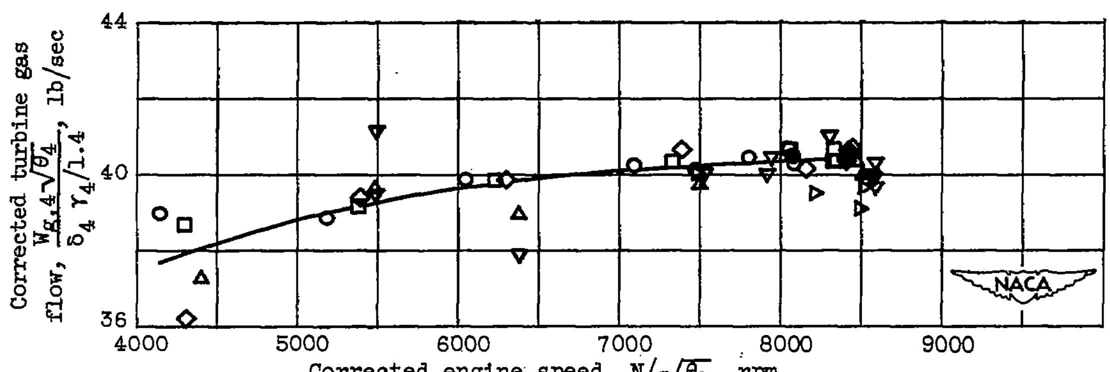


(d) Turbine pressure ratio.



(e) Corrected turbine gas flow.

Figure 14. - Concluded. Variation of turbine-performance parameters with altitude and corrected engine speed; flight Mach number, 0.19; engine on electronic control schedule.

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